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SPACE BIOLOGY AND MEDICINE

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To the Editor in Chief of the Journal "Kosmicheskaya Biologiya i Meditsina" (Space Biology and Medicine), Academician V. V. Parin:

The Ministry of Health of the USSR hereby congratulates the editorial board of the journal "Kosmicheskaya Biologiya i Meditsina" (Space Biology and Medicine) on the publication of the first issue of their journal.

The many scientists, physicians, biologists, physiologists, and psychologists who are occupied with the solution of the complex problems involved in making it possible for man to live in outer space have received a remarkable forum for the exchange of experience, scientific discussions, and the publication of the results of experimental investigations.

The magnificent achievements of Soviet space science demand the utmost perfection of the methods of investigative work in the area of the selection, training, and preparation of cosmonauts. The present stage of utilization of space, characterized by a transition from orbital flights to prolonged interplanetary voyages by spaceships with room for several persons, has produced the need for a theoretical evaluation of the accumulated scientific data, their deep analysis, and the reorientation of our research in new directions in order to guarantee the harmlessness of long flights and the reliability of the human link in the "man-spaceship" system during the performance of these flights.

I would like to wish all scientists working in the area of space biology and medicine great success in the noble task of solving these problems. It is obvious that our successes in this field will at the same time have a broad impact on the entire practice of Soviet medicine and will enrich Soviet medical science with new discoveries.

I would like to wish the editorial board of this journal a bold, theoretically well-founded, and creative approach to the illumination of the achievements of this constantly developing new science - space biology and medicine.

Let the flame of science, lighting the way of the cosmonauts to the unknown worlds, be forever bright!

Minister of Health of the USSR, Academician B. V. Petrovskiy

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SOME OF THE MAIN PROBLEMS OF SPACE BIOLOGY AND MEDICINE

N. N. Gurovskiy, V. V. Parin, V. N. Pravetskiy

ABSTRACT. The authors outline some of the major problems encountered in the development of space biology and medicine. Physiological and psychological aspects of spacecraft crews and habitable environments are discussed in detail.

The penetration of man into outer space is one of the most remarkable achievements of contemporary science and technology. The flights of Soviet and American astronauts represent only the first steps on the long road toward the mastery of space for the purpose of utilizing the untapped resources of the Universe to satisfy human needs. /4*

The results of studies carried out during the flights of animals and men in space have so far made possible the solution of only a few of the special problems of space medicine, out of the tremendous number of scientific problems connected with guaranteeing the possibility of prolonged voyages through space.

It could be said that space biology and medicine are presently at the stage where they cannot yet solve the principal problems standing in the way of the successful accomplishment of long space flights, but where they are able to formulate them more or less correctly and indicate a pathway toward their solution.

The magnitude and complexity of the work which stands before us is indicated by a simple enumeration of the problems which are currently facing space biology and medicine. Some of these are:

- the effect of prolonged space flight on the physiological and functional integrity of the human organism, and the development of means for protecting man against the unfavorable influences of flight through space;
- the characteristics of the formation of a habitable environment in the cabin of a spaceship during prolonged flights, and the effect of the spaceship crew on this process;
- the biological and psychological compatibility of the members of the crew during a prolonged flight; the prediction of their condition and behavior;
- the role of the cosmonaut in the direction of the spaceship and its systems;
- the problems of protection against radiation;
- the collection, storage, processing, and analysis of physiological data;
- the selection and training of cosmonauts;
- medico-technical problems in the creation of life-support systems.

*Numbers in the margin indicate pagination in foreign text.

This list could be made considerably longer. Since it is not our intention to analyze each of these problems, we would like to draw attention to just one of them: the problem of the adaptation of the organism to a prolonged stay under conditions of weightlessness.

An analysis of the results of the flight of the spaceship "Kosmos-110", with two dogs on board, showed that rather significant changes developed in a number of physiological systems of the animal organism as a result of a 22-day period under conditions of weightlessness. These changes were reversible, but were nevertheless quite pronounced.

The significant weight loss by these animals, due mainly to muscular atrophy, has already been reported in the press; there was also a disruption of water and salt metabolism, reflected primarily in an increased excretion of calcium, potassium, and sodium salts from the body; disturbances in the coordination of movement; disruption of orthostatic stability, etc. These data are in agreement with the findings of American scientists, who noted similar shifts in most of their cosmonauts. /5

It has also been pointed out that the dynamics of the changes in some physiological parameters during the course of a flight indicates a tendency for the organism to adapt to conditions of weightlessness. However, this is only a first impression which requires further clarification and verification. Only one thing is clear, that rather significant rearrangements in a number of physiological systems take place in the organism under conditions of weightlessness. The mechanism of these rearrangements is still unclear, however, and we still have no answer to the principal question: it is possible for an organism to adapt completely to new conditions of existence, and might not such rearrangements be so profound that they would lead to severe complications on return of the cosmonaut to normal gravity?

In order to guarantee the success of prolonged space flights and maintain a high level of efficiency during periods of duty, it will be necessary to use special means and methods to protect the organism against the unfavorable influences of the flight, especially weightlessness. The development of such techniques is one of the most important tasks of space medicine. However, without a clear understanding of the mechanism of action of prolonged weightlessness, and without a study of the intimate processes which take place in the body under these conditions, any scientifically based selection of prophylactic agents and methods would seem extremely difficult and practically impossible.

Consequently, in order to solve the theoretical questions connected with the accomplishment of long space flights, one of the central problems of space biology and medicine in the immediate future will be to carry out a series of experiments designed to clarify the mechanism of the response of the organism to a prolonged stay under conditions of weightlessness. These studies should be carried out primarily at the cellular and molecular level with a broad application of contemporary morphological and biochemical research techniques. In this connection, the study of hemodynamics, the physiology of digestion, metabolic processes, and especially mineral metabolism must be considered

essential. Another aspect of the study of the adaptive processes, which is no less important, is the study of the neuroreflex and humoral elements in the regulation of functions, shifts and connections between systems, and the function and interaction of the analyzer systems under altered conditions of existence.

All of the problems of space biology and medicine enumerated above, and many others, will acquire still greater importance as part of a general program for the study and utilization of space in connection with the desired increase in both the complexity and duration of space flights, with the emergence of man into space and onto the planets.

The solution of the problems which have been posed will require a broad scientific effort, both under terrestrial conditions and during space flights. In this regard, the studies at the terrestrial level must be brought to a higher technological plane and should be carried out in agreement with the new organizational structures.

This is due primarily to the fact that guaranteeing normal function and a high working capacity for a man during a complex and prolonged space flight requires a preliminary evaluation of a series of new factors, such as the effect of man on the environment which is being created, the effect of this /6
environment on the organism, and the nature of its responses. Consequently, along with the search for theoretical approaches to the solution of the problems which have been posed, we are in need of concrete laboratory testing and simulation, the selection of the optimal solutions from the points of view of technology and design, and the performance of a large number of sufficiently prolonged trial studies with man as the subject. Only after the completion of a whole cycle of scientific studies and experimental design work, approximating the conditions of the experiments as closely as possible to the parameters of the actual intended flight, will it be possible to make recommendations as to the characteristics of the environment in the cabin of the spaceship; the biological and psychological compatibility of the members of the crew; the role of the cosmonaut in the control of a spaceship; protection against radiation; the collection, storage, processing, and analysis of physiological information; and the selection and training of cosmonauts.

All of this can naturally only be accomplished with the close collaboration of specialists in space medicine and the representatives of the nonmedical professions. The specific nature of the organizational work in the area of space biology and medicine requires that this collaboration be realized in the very early stages of the research effort. Unfortunately, such an approach to the organization and performance of the work does not always receive the necessary attention on the part of either the engineers and technicians or the medico-biological personnel, due to its novelty and complexity; until now, this type of approach has found a clear expression only in the solution of problems related to the medico-biological aspects of prolonged and complex space flights.

The problem of the search for ways of protecting man against the unfavorable effects of the extremal factors of prolonged space flights, especially

weightlessness, looks somewhat different. For quite understandable reasons, this problem can be solved with sufficient completeness only during space flight itself, and here a special role will be played by flights of varying degrees of complexity and duration, intended specifically for the solution of medico-biological problems. These experiments must be carried out on a variety of biological subjects, both with the maximal use of automation and with the participation of a biologist and a physician in the space flight. The very performance of such studies in flight represents a complex scientific and design problem requiring significant contributions of both physiologists and engineers.

REVIEWS AND LECTURES

EXPERIMENTAL RESEARCH INTO SPACE PSYCHOLOGY*

V. V. Parin and F. D. Gorbov

ABSTRACT. The authors emphasize the significance of space psychology as an independent branch of science. Historically, they distinguish two stages: the one prior to, and the other following, the first manned space mission. The paper describes tasks involved in astronaut training. It contains the results of investigations performed using different techniques, including methods of group psychology research. Particular importance is attached to clinical models, i.e., diseases which are, to a certain extent, similar to syndromes developing under extreme conditions. Flight studies involve an analysis of the performance and the application of uncomplicated tests. Post-flight investigations combine pre- and inflight research findings. In this connection, new research purposes are mentioned.

At the present time space psychology represents an independent branch of science, having its own subject and its own method of research. After the first manned flight, that of Soviet cosmonaut Yu. A. Gagarin, space psychology entered into the second phase of its development. /7

In the first phase, the reaction of man to the environment of space flight and his adaptability to this environment could only be predicted. These predictions were based, as a rule, on indirect data (flight experience, animal flight into space, brief flights for the study of weightlessness, and "clinical models").

In the second phase the "prediction service" retains all its significance with respect to all that is characterized by primary explorations: the first actual extended flight, G. Titov; emergence of man into space, A. Leonov; the first flight undertaken by a woman astronaut, V. Nikolayeva-Tereshkova; the first group flights, A. Nikolayev and P. Popovich; the first flight of a multiseat spaceship with a functional distribution of responsibilities, V. Komarov, K. Feoktistov, and doctor-cosmonaut B. Yegorov; the first group flights of American astronauts with rendezvous of the spacecraft Gemini 6 and 7, etc.

A significant characteristic of the second phase was the accumulation of not only indirect, but also of direct positive data, obtained during the flights of Soviet and American astronauts.

* - This article comprises a report made at the 18th International Congress of Psychologists (Moscow, August, 1966).

In the course of posing and developing the psychological problems of man's first flight (selection, preparation) the following tasks were set up:

1. Selection according to contraindications in the framework of medical psychopathology and neuropsychology.
2. Determination of the functional neuropsychological threshold of the astronaut by means of trial loads, which in our country were developed on the basis of the simulation principle (F. D. Gorbov), i.e., simulation of anticipated space flight factors under conditions existing on Earth.
3. Detection of outstanding positive individual psychological characteristics in man, based on the evaluation of dynamics indicating successful preparation. Here the task of selection according to contraindications gives way to the selection of the outstanding candidate, best prepared for the specific flight; the selection (matching) of a crew for a spaceship is based on compatibility, good interrelationships, and interrelated activity.

New and original methods of experimental psychological research were established in order to resolve the above tasks. /8

These new methods were based on stability experiments in the "prescribed operational assignment" (i.e., activity according to a program established beforehand). The stability in the "prescribed operational assignment" was tested with respect to three kinds of influences: 1) resistance to extremal factors: g-load and weightlessness, with execution of acrobatic exercises while they were being assimilated; hypoxia, isolation, and thermal influences; 2) distant irritants of unexpected and strong effect (shrill sound, light flares); and 3) specifically effective irritants: disturbances related to a useful signal, formulation of assignments with extremely complicated selections, based on the confusing action of the prompter and sidetracked by untimely corrections.

Principles applied to the evaluation of results were changed. The criteria of errors, productivity, and efficiency (these criteria are not reliable since they vary depending on the exercise) were no longer of prime importance; they were replaced by the criteria of physiological stability indicators.

Only physiological discomfort producing a sharp decrease in activity is evaluated as a negative indicator. This is the basis for the complexity of experiments and the evaluation of results.

"Complexity" in this case means the joint collaboration of clinical personnel: psychoneurologists (who perform the observations), psychologists (who perform the setting up and the "direction" of the experiment), and neurophysiologists (who record and evaluate the electrophysiological, biochemical, and other data).

Evaluation of activity efficiency is performed primarily to determine moments of the onset of considerable difficulties in performance.

Clinical observations of nervous and psychological disturbances are particularly important. They may be regarded as stable examples or prototypes of

those deeply dynamic and rapidly occurring states which are observed in healthy persons in new and unusual conditions.

Varied difficult conditions occur in experimental as well as in real space flights. These conditions can be characterized as specific syndromes corresponding, to a certain degree, to persistent nervous disturbances encountered in everyday life. There have been cases of paroxysmal memory and observation disturbances in healthy persons which occurred during "a rapid development of unexpected events" thus interfering with normal reactions. Attacks of retroactive retardation of V. M. Bekhterev and the "short nervous collapses" of S. N. Davidenko, are representative of the above. In simulated conditions of the human body and spacecraft positions, certain characteristics similar to the gnostic phenomena in Parkinsonism and to the phantom phenomena experienced by amputees could be observed. Difficulties experienced in space and neurotic reactions in isolation are related to the psychical automation syndromes of Kandinski-Clerambeaux and other space phobia (kenophobia, claustrophobia, bathophobia, acrophobia, etc.).

Development in this direction is characterized by interpenetration of clinical data and the results of the first space experiments, with beneficial results for both fields.

During the prediction phase, the clinical data were not only beneficial for selection, but also for the planning of a series of experiments. On the other hand, during the actual space flights, it became possible to apply the results /9
to the analysis of certain clinical disturbances.

The detection of particularly positive (outstanding) characteristics in an individual completely dominates such factors as "perfect health" in medical as well as psysiological respects.

In the course of preparing for and becoming an astronaut, an individual forms such qualities as space courage, adequacy of reactions to "novelty," and high adaptability to "reactors" (through concentration on handling instruments specifying direction and position, perception of the surrounding media and of one's own position, adaptation of the vegetative-trophical mechanisms to functioning under complicated conditions, respiration under increased pressure, use of antiload and compensating devices and instruments). This list could be extended; however, suffice it to say that the most important characteristics in an astronaut are adaptability and the ability to learn.

Adaptation-vegetative systems and behavioral patterns cannot be regarded as equivalent. One need only recall the first experiments of the influence of weightlessness on the human organism. Then it was assumed that coordination disturbances would be the important factor. The first flights, however, showed that there are no significant movement coordination disturbances. Locomotion as well as complicated psychomotor ability were not disturbed; the so-called norm-deviations were due to the novelty of the surroundings in which the required motions had to be performed, as well as to the changed "behavior" of objects in these surroundings.

The problem of the hitherto unrecognized psychomotor ability, tonicity, and resistance reflexes proved to be more complicated. Sensations of pressure on various parts of the body in rigid immobilization in a chair caused false perceptions of body orientation. It is natural that similar occurrences are related to the difficulties of achieving sensory corrections in weightless conditions.

In situations where simultaneous and independent changes of accustomed afference occur on the threshold of "sensory input" as well as on the threshold of the inner canals of afference complicated conditions may appear in connection with existing emotional and adaptation-vegetative shifts. However, these are completely surmountable.

The study of the reaction of man to changed afference was carried out under simulated as well as natural conditions. The problem of the formation of the "body-in-clinic" scheme and "man-spacecraft" and "man-spacecraft surrounding space" schemes was studied specifically on the basis of flight experience, centrifuge experiments, and on special stands.

As a result of these studies, a concept was suggested on the important role of preliminary "internal playback" of future actions and the role of the formation of anticipation of forecasting systems (P. K. Anokhin; S. G. Gellershteyn).

The accumulated information was studied in simulated experiments of the various communication forms (oral, signals) by introducing inteference close to the useful signal. The results of these experiments were then compared with the results of sensory deprivation experiments (F. D. Gorbov, F. P. Kosmolinskiy, V. I. Myasnikov).

Much has been said about significant displacements in the neuropsychical sphere under the influence of "sensory starvation" in connection with sensory deprivation. In protracted isolations the following was observed: decrease in efficiency, general physiological tonicity, and observation ability, impairment of the sensory-motor reactions, and occurrence of nervous tension, sometimes even apathy (Heron; Hebb; Ruff; Hahna, F. D. Gorbov; V. I. Myasnikov, and others), and sleep disturbances. However, in spite of these results, it should be pointed out that, due to the strong motivation in the present system of selection, screening, and preparation of astronauts, the appearance of severe pathological conditions, such as psychic depressions, hallucinations, and even disintegration of personality, can hardly be expected, as was once believed by some scientists. /10

On the contrary, at the present time the problem of isolation is regarded as merely an influence on the nervous system, necessitating high resistance to changed afference, the development of self-control and restraint, and in group experiments, development of a high sense of compatibility. These factors were the main points of discussion during the 18th Internal Congress of Psychologists in Moscow in August, 1966 (Aarons, Golubinska, Demos).

There was a tendency to compare experimental results of protracted isolation (characterized by a strong stability in the interrelation of man and

space) with the experimental results in which the change of space factor plays the central role. For this purpose, the reactions of pilots during flights with aerial refueling were studied (F. P. Kosmolinskiy, F. P. Kosmolinsky et al.). Specifically, a relationship was observed between neuroemotional tension of the pilot and the abrupt change in the spatial field of operation. It appeared that these facts have a direct and continuous connection with the formation of "man-spacecraft surrounding space" schemes. Objective classification and quantitative formulation of the results of psychological investigations became possible due to the registration of physiological and biochemical indexes. The data obtained, besides their primary significance in space biology and medicine, have a direct bearing on the general theoretical problem of electrophysiology and biochemical behavioral correlations.

The impossibility of staffing small working teams (squads, crews, or commands) solely on the basis of previously compiled individual characteristics led to the necessity for new experimental methods for the evaluation of correlated integration of group activities.

For this purpose, models were devised of the operational activities on the regulation of controllable plants, in order to utilize them in brief experiments with subsequent verification of the results thus obtained under natural conditions.

In such experiments, continuous activity was organized with a compulsory programmed sequence of the functional operations and a specific time limit was set. The operator (a member of the group) evaluated the results of his own work by means of indicators.

Continuous activity by all members of the group is an essential condition of group experiments, since it assures the principal methodical requirements of simultaneous and interrelated (interdependent) activity. In addition, the requirement that each experiment be reproducible when repeated, and that not only partial, but also final results of the work of each group member be objectively recorded, as well as the results of total group activity, were observed. Thus the opportunity of evaluating the whole process was presented (individual tactics of each member and the strategy of the group as a whole). These experiments are based on the "homeostat" principle, i.e., a control system consisting of 3 or more instrument panels according to the number of subjects.

Each member of the group adjusts his indicator needle to zero. All the /11
devices are interconnected. The research worker, from his control panel, can vary the degree of difficulty of the problem. The problem is regarded as completed as soon as each operator returns his needle to zero. Oscillograph recordings make it possible to check the movements of all levers and all needles, not only of the group as a whole, but also of the tactics of each individual operator.

These experiments verified the fact that the effectiveness of the group action cannot be predicted a priori on individual criteria, the need for strategy change of the group as a whole by strengthening the interrelated

connections when the interrelation coefficient passes through critical value (K= -0.6), and the replacement of the "parity" principle of the group by an "authoritative" one. Criteria of "trained" and "in training" were obtained in problems with increasing degrees of difficulty.

During such experiments temporary replacement of one member of the "final group" as well as regrouping were used.

The theoretical possibility of achievement of higher level by any group was demonstrated as well as the role of "leader" by individual operators, however, the theoretical findings did not always agree with the practical results.

During research on interconnected oral activity (paired oral test according to M. A. Novikov), various forms of interdependence were made apparent (intrusions, corrections, promptings, and "cut-off" effects). In controlled, "full-scale experiments" with prolonged group isolation, subject reactions to crowded conditions were noted. The "body scheme" concept was supplemented by the concept of an "aureole," reflecting the space requirements of each member of the group.

These same experiments included the direction of group dynamics to explore the distribution characteristics within the group and the various communication structures in regard to the placement of the group members (for instance: in "wheel-form" or in "chain-form" at the oars of a team of eight). It was noted that the success and performance results of the oarsmen in real conditions fully correspond to the experimental results of a hemeostat. It was also possible to establish the role of a helmsman as a leader and the significance of number 4 (5) as a "relay" leader, passing the tactics of the leader along the functional "oarsman-chain." Thus, important starting positions for the development of similarity criteria were established; this is an important factor for the evaluation of the experiment as a model of activity.

In the course of the development of concepts of the model character of the group experiments, hypothetical comparisons were made between the group as a unit and the organism as a complicated system consisting of subsystems. This was an important intermediate stage in the development of effective methods of preventive treatment and preservation of mental health in complicated conditions.

It should be noted that group methods, which were considered for the purpose of surmounting the restrictions imposed by "individual" methods, not only did not erase the role of the individual, but on the contrary, proved to be a powerful means for revealing individual characteristics.

In the course of preparing for the first manned flight, there arose for the first time the possibility for an adjustable reliability prediction of succeeding action stages according to the partial results of the preceding stages, and the possibility for the determination of a candidate's dependability on his first space flight according to the overall results of the entire training period.

During the space flight, psychological research was primarily concerned with evaluation of realistic activity of the astronaut, specific research, however, was characterized by short, not overburdening tests. During the flight, qualities such as space courage, the ability to relax in tense conditions ("waiting scheme"), self-reliance, and self-control were checked and confirmed. /12

The results of the space flights were also analyzed (together with experimental data) in order to establish the optimal work-rest conditions of spacecraft crew members (B. S. Alyakrinskiy 1966).

Observational and experimental data in the post flight period made it possible to combine the entire process of the astronaut's activity into a unified whole during training and actual flight. In this phase the interesting phenomenon was observed, that of "transfer" of the experiences of the astronaut who already had been in flight to his comrades preparing for future spaceflights.

At the present time, space psychology faces new, important, and complicated tasks.

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PROBLEMS OF GASTROENTEROLOGY IN SPACE MEDICINE AND THE PHYSIOLOGICAL BASES OF COSMONAUT NUTRITION

I. M. Khazen

ABSTRACT. The author reviews the literature and his own findings on physiology and pathology of the gastrointestinal tract in response to stress exposures. Three problems which are of theoretical and practical significance are indicated: 1. effects of space flight factors on the function of the digestive system; 2. role of the digestive system in the development of motion symptoms during space flight; and 3. development of physiological requirements in relation to long duration space missions. Repeated exposures of the human organism to accelerations, hypoxia, and other factors regularly applied following their after-effects result in its pronounced adaptation. The author discusses techniques to prevent digestive disturbances and to maintain homeostatic functions of the human body.

Since Yu. Gagarin made the first orbital flight on the space ship "Vostok," /13
the total time logged by American and Soviet astronauts has exceeded 2000 hours.

Not only have pilots who have had jet flight training spent time in space; persons who have had no such experience have done so also: the woman pilot V. Tereshkova and the scientists K. Feoktistov (an engineer) and B. Yegorov (a physician).

Studies of the functional state of cosmonauts have been conducted systematically at the different levels of flight and in outer space as well. After A. Leonov (Voskhod-2) had successfully performed manual operations outside of the ship, this feat was duplicated by the American astronauts E. White, E. Cernan, M. Collins, and R. Gordon (Gemini #4, 9, 10, 11).

As a result of these experiments, it became generally accepted that the necessary working capacity is preserved and that man is psycho-physiologically stable during space-flight, despite the fact that the performance of tasks involved a much greater loss of time than had been estimated. At the same time, the separate functional manifestations which characterize the shifts in the centers of autonomic functional regulation continue to be interpreted in various ways. In the first place, this involves evaluating the role of the vestibular apparatus in the incidence of motion sickness (or the so-called space form of the disease - "satellite sickness").

During the first stage of their development, space biology and medicine directed all efforts toward the study of problems of the general endurance of man

to space flight, depending chiefly on the indexes of the functional state of the cardiovascular system, respiration, and vestibular apparatus.

Attention was also devoted, as far as was possible, to the interaction of the analyzers. On the basis of the accumulated facts, the hypothesis was formed that the transitory shifts in the systems mentioned during flight and in the post-flight period reflect the dynamics of the adaptive reactions, indicating either good or satisfactory endurance by the organism of the different factors of flight. However, the concept of good endurance by no means includes the absence of concealed changes in the internal organs and does not reveal the essence of those compensatory mechanisms which are the basis of the establishment of good endurance (I. M. Khazen). It would seem that such a hypothesis could only be considered a unilateral one, inasmuch as the afferent innervation from the interoceptors of the alimentary and other systems of the organism, as well as the work of these systems under conditions of flight, remained outside of the field of vision of the scientists. The same might be said about the evaluation of the role of the vestibular apparatus in the incidence of antonomic disturbances in individual cosmonauts, resembling to some extent the symptoms of motion sickness (G. L. Komendantov and V. I. Kopanev; Yu. M. Volynkin et al.).

After the 25-hour flight of G. Titov, the vestibular apparatus attracted the attention of scientists and occupied the dominant position in space physiology. The autonomic manifestations described by the cosmonaut (unpleasant sensations and vertigo when the head was turned suddenly, a feeling of heaviness /14
in the head and pressure in the region of the superorbital arches, nausea, decreased appetite, etc.) began to be considered the result of an isolated disturbance in the function of the vestibular apparatus and not of impairment in the interconnection of all the afferent systems and the algorithms for the processing of information in the central nervous system. In this connection, no attention was given to the rather late manifestations of vestibuloautonomic disorders in the cosmonaut.

Autonomic disturbances of varying degree and type could be noted in the majority of the astronauts. Thus, during his 34-hour flight on the space-ship Mercury-9, G. Cooper noticed morbid sensations when he swallowed, "fatigue from eating, and loss of appetite. Of the 2000 to 2500 kcal of food available to him according to the program, he consumed only 690 kcal. No physiological analysis of these symptoms has appeared in the literature. Only those questions related to the technological aspects of taking food have been discussed (Johnston et al.).

According to Berry's data, when G. Cooper left the space capsule after landing, he was observed to be in a state resembling syncope. The disturbances in blood pressure and pulse rate persisted for 7 to 19 hours after the flight ended.

As the time for landing approached, the doctors began to notice that despite the good environmental conditions and sleep, G. Cooper was markedly fatigued (Berry). As the doctor pointed out, one hour before reentering the dense layers of the atmosphere he had taken 5 mg of dextro-amphetamine sulfate (the drug has antihistaminic properties and is used as a symptomatic drug for seasickness).

Cooper lost 3.4 kg of weight (due especially to sweating) which was reflected by an increase in the hematocrit (43% before and 49% after the flight). Cooper, as opposed to W. Schirra (the pilot of Mercury-8), complained of dizziness (testifying to deterioration in blood flow and brain oxygen supply) when he assumed the vertical position after leaving the space ship. All the impairments observed in the functional state of the cardiovascular system made it possible to diagnose the classical syndrome of orthostatic hypotension. It should be mentioned that despite the fact that Schirra was in the weightless state for only 9 hours, the hypotensive condition persisted for approximately the same length of time in his case after Cooper's flight - approximately 18 hours (Dietlein).

Even A. Sheppard (the pilot of Mercury-3), during his very brief flight (5 minutes of weightlessness), was noted to have strongly pronounced autonomic dysfunction.

The loss of body weight, in proportion to the length and conditions of the flight and connected, as one might think, with disturbances in the mechanisms for controlling water and mineral metabolism, has been observed in all cosmonauts.

The results of studies of the functional state of the crew of the Voskhod, which were the first to be carried out not only by telemetry but also by direct observations made by the physician aboard the craft, are of great interest. B. Yegorov and K. Feoktistov were reported to have had illusions of being upside down which occurred 2-3 hours after the flight began and lasted until reentry. Along with the illusory perceptions of Feoktistov and Yegorov during orbital flight, they were also noted to have an unpleasant sensation of brief dizziness (vertigo) when they moved their heads either moderately or abruptly. At nearly the same time, autonomic disturbances occurred. In Yegorov the latter were expressed in the form of decreased appetite and unpleasant sensations in the epigastric region. These manifestations reached their maximum by the 7th hour of the flight. These symptoms were present to a lesser extent in Feoktistov. /15

Vestibulometric studies have shown that the thresholds of excitation of the vestibular analyzer by direct current are not substantially different under weightless conditions from those noted in the pre-flight period. These facts, established for all crew members (V. M. Komarov, K. P. Feoktistov, B. B. Yegorov), are of considerable differential-diagnostic significance.

As analysis of the data characterizing the reactions of the different systems of the organism (the central nervous, respiratory, and cardiovascular systems, and the stato-kinetic, visual, and other analyzers) has revealed that they are predominantly adaptive in nature. In this connection, it was emphasized that the adaptation to abruptly changed conditions in the external environment is related to tension in the compensatory mechanisms and involves a decrease in work capacity (Yu. M. Volynkin et al., 1966).

Here, as is well known, new problems arose whose solution was undertaken by means of physiological experiments on function control in the weightless state

during the 22-hour flight of the biosatellite "Kosmos 110" (B. B. Yegorov; V. V. Parin).

Spatial illusions which were expressed as a sensation of flight in the upside-down position were also observed in Gagarin, Titov, and Popovich. However, these were transitory in character and were only observed at the time of transition from excess gravity to weightlessness (I. I. Kas'yan et al.).

Examples may be cited of functional impairments in other cosmonauts as well; however, for purposes of differential analysis, the facts pertaining to the feelings of Titov and Cooper (men with about the same amount of flight training) are of greatest interest. Although each orbital flight was unique, and the composition of the gaseous environment in the cabins of the Vostok and Mercury capsules was different, the flight conditions are still comparable since the flights were very close in duration.

The large amount of data currently available to space physiology makes it possible to undertake a wider approach to the analysis of the facts, and not only from the standpoint of the vestibular effects.

The question of the leading roll played by the vestibular apparatus in the incidence of motion sickness during space flight was under discussion as soon as the concept of the space form of motion-sickness came into being.

In the past year, critical remarks have often been made about the need for reconsidering the hypothesis already formed. This view was voiced at the XV International Congress on Aviation and Space Medicine held in Prague in September-October of 1966 (Campbell, Graybiel, et al.).

In our earlier papers we gave consideration to the symptoms described by Titov from the point of view of extralabyrinthine effects (I. M. Khazen, 1964), using as a premise the hypothesis of the formation of new inter-center interrelationships caused in particular by the increased sensitivity of the vomiting center.

The weightless state occurring after exposure to acceleration, as a physiological stimulus, exerts its effect on the altered basal activity of the nervous and humoral-endocrine regulatory systems. The new functional level of the reflex centers and also of the organs and their systems in the body as a whole, caused by the totality of extremal effects preceding (pre-flight training, cross-directed acceleration during take-off) and accompanying (limited movement, changed biorhythm, emotional tension, etc.) weightlessness, could, in individual cases, bring about the appearance of vestibulo-autonomic symptoms. Subject to this same analysis, are those functional inter-system interrelationships which are formed during weightlessness, on the basis of which the acceleration of reentry also exerts an effect. The role of the digestive system in the mechanisms of formation of the extralabyrinthine reactions will be the subject of an independent publication. /16

In trying to uncover the nature of any of these functional manifestations in cosmonauts and their interconnection with the mechanisms of the different

regulatory levels, we accepted the position that there is greater resistance (stability) when the corticalized functions are exposed to extremal effects than when the autonomic functions are so exposed. It is assumed that the cerebral cortex organizes the guidance of the lower levels of the nervous, humoral, and trophic regulations in such a way that the evolutionary earlier functions change to a greater extent than the functions that are physiologically more recent (I. P. Pavlov, L. A. Orbeli; I. P. Razenkov, 1948; I. M. Khazen, 1963).

In order to conduct such a differential analysis, we used the neuroglandular apparatus of the gastrointestinal organs - the indicator of the reactions of the organism to extremal effects - as a model. This model has been in wide use since 1878 when N. Sokovnin first selected the salivary glands to study the effect of oxygen starvation on the organism. In 1905, I. S. Kadygrobov studied the effect of muscular work on the activity of the pepsin glands of dogs. He harnessed a dog with an isolated stomach to a cart and made it haul a load weighing 5 to 10 kg. In conjunction with the simplicity and accessibility of the technical devices used in these experiments, it was possible to perform them not only with the participation of humans but also, on a relatively physiological plane, on the small animals (frogs, rats, rabbits, etc.) used for the problems of space physiology. The following basic problems can be identified here according to their theoretical and practical value:

1. The effect of the factors of space flight on the functions of the alimentary system.
2. The role of the alimentary system in the mechanism of occurrence of seasickness during space flight.
3. Development of physiological and biochemical bases for the nutrition of cosmonauts under conditions of prolonged flight.

The operation of the organs of the gastrointestinal tract is extremely complex and multiform. It includes secretory, enzyme-producing, enzyme-secreting, excretory, incretory, absorptive, and motor functions. The gastrointestinal tract also has the unique function of interstitial metabolism. In this, a substantial role, especially in the production of the B and K group vitamins, is played by the microflora. The digestive system on the whole participates in regulation of the relative continuity of the internal environment of the organism and is a depot for nutrient substances (I. P. Razenkov, 1948).

For many years, studies have been made of the effect of different extremal factors (hypoxia, acceleration, vibration, physical loads, abrupt changes in temperature, radiation, toxic substances, emotions, fatigue, qualitatively differing diets) on the operation of the gastrointestinal organs. Likewise, data have begun to be accumulated concerning the effect of weightlessness and other factors of the space environment. Under conditions of immersion subgravitation, significant disturbances were found in the evacuation of protein and fatty foods from the stomach. There was also a disturbance in the absorption of these /17
products and an accelerated absorption of water in the small intestine (Baranski et al.). It is interesting to note that the general physiological reactions of the organisms to extreme exposures can be simulated by the neuro-glandular apparatus of the stomach. The effects of isolation, limited movement, noise etc.,

are being studied in large scale experiments with rats. The pathogenicity of a particular stimulus can be evaluated on the basis of the number of gastric ulcers formed. This same model is also used for solving problems of pharmacological treatment for prophylactic purposes. Studies are being conducted on different animals in which the authors (Simler et al.; Pare, Foltz; Korany and Endoczi, and others) are following the traditions of Soviet science. Selective functional and structural disorders of the glands of the body and gastric fundus were found for the first time under conditions of decreased pressure in a barochamber by E.S. Zel'manova and Yu. M. Lazovskiy, in an alpine climate by V.M. Rubel' and I.M. Khazen, and during acceleration by P.M. Suvorov. An important symptom of these disturbances is the appearance of blood in the gastric juice.

An analysis of the neurophysiological mechanisms of ulcer formation as the result of extremal exposure has revealed the role of the hypothalamus, the anterior section of which acts via the vagus and splanchnic nerves, while the posterior section functions hormonally via the hypophysis-adrenal system. Peptic ulcers, which seem to be caused by emotional influences, are related to the limbic region of the cerebral cortex. Efferent connections between the stomach and hypothalamus and other centers of the cerebrum are now the object of intensive research (V. N. Chernigovskiy; G. G. Gasanov; I. T. Kurtsin; Yu. L. Pines). An interdependence has been established between the extent of adrenal stress, the functional state of the gastric glands, and the incidence of acute peptic and duodenal ulcer (Woldman).

The data cited testify to the increased interest in the problems mentioned. These problems were also the subject of the extensive review of the literature on the physiology and pathology of the gastrointestinal organs under exposure to extremal factors published by K. Pfeiffer in 1965 un der the title "Space Gastroenterology."

In his exposition of the basic features of the effect of each individual stress-factor, Pfeiffer, to an extremely limited extent, cites the works of Soviet authors who have made wide use of the alimentary glands for the study of the biodynamics of the physiological processes and the conditions of general correlation of the functions of the organism. Among the papers which could have been included to expand this survey substantially, are the fundamental research papers from the laboratory of I. P. Razenkov: "The Quality of the Diet and Bodily Functions" (1946) as well as "Digestion at High Altitudes" (1945); the works of G. V. Fol'bort devoted to the study of the processes of exhaustion and the restoration of the function of the salivary glands as a basis for the physiological understanding of exhaustion and rest; the paper by K. V. Smirnov and M. F. Nesterin in which the secretion of digestive juices and enzymes under the influence of radiation was analyzed (1962); and the papers of N. I. Putilin on the analysis of the mechanism of disturbances in gastric secretion which occur after prolonged unusual diets. As a result of keeping dogs on diets with partial feeding for long periods (or with other deviations from a normal diet), changes of a stable nature appeared which were linked with impairments in the mechanisms of trophic functional regulation. In a morphological analysis, destructive changes were found not only in the mucous and submucous membranes of the stomach, but also in the nerve cells of the Auerbach plexus. Significant changes in the digestive system also occur inevitably after a prolonged quali-

tatively varied diet. In this case, the functional and structural disturbances /18
occur in conjunction with changes in the intestinal microflora (F. T. Grinbaum and E. I. Al'tshuller). The results of the above-mentioned studies acquire theoretical significance in connection with the new stage of space conquest - the stage of prolonged stays in interplanetary space. Under such conditions the diet of the cosmonauts will be based to some extent on lyophilized or possibly synthetic foods (V. P. Bychkov et al.; A. M. Ugolev).

Dietlein considers the changes in the digestive system to be of great significance. He feels that after the abrupt shifts which occur in the function of the gastrointestinal organs under conditions of weightlessness, a new, markedly abnormal level of activity appears. Dietlein's view on the presence of a prolonged after-effect in such cases is in agreement with the conclusions of I. M. Khazen et al. On the other hand, this after-effect as a reflection of the total number of metabolic and structural changes has acquired the significance of an important indicator of the reactive capacity of the separate functional systems of the organisms as a whole, even during the period of alpine expeditions for the study of the limits of adaptation to hypoxia, during the establishment of the fact of the "adaptation gap" by its heralds (V. M. Rubel' and I. M. Khazen).

A prolonged after-effect is sharply reflected in the processes of gastric juice and enzyme secretion during acceleration and other types of stress.

Under the influence of an 8 G acceleration of 3 minutes' duration in the ventro-dorsal direction, impairments were noted in coordination and in the periodic motor activity of the stomach and especially the duodenum. The after-effect period lasted about 3 weeks. Along with these changes, pronounced impairments in the evacuator function of the gastrointestinal tract, consisting of accelerated gastric emptying on a milk diet and also accelerated movement of the last portions of meat and milk through the small intestine, were noted in dogs (T. V. Volkova et al.).

Under otherwise equal conditions, the secretion of digestive juice from the intestinal loops is decreased during the first few days after exposure. Later on, considerable fluctuations in the sense of hypo- and hypersecretion appear with a long after-effect period of 8 to 9 weeks. The changes in enzyme activity occur after the 3rd day: amylase, enterokinase, and alkaline phosphatase activity increase considerably and are maintained at a high level for different periods of time for each enzyme; for alkaline phosphatase the after-effect period is equal to approximately 4 months (V. Ye. Potkin).

Trophic disturbances were also detected in experiments designed to study the dynamics of pancreatic secretion and the pancreatic enzymes (amylase and trypsin). In individual experiments the tryptic activity of the pancreatic juice immediately after exposure was considerably lowered. Later, the enzyme activity increased, but the after-effect period was the same as for the intestinal juice enzymes.

Immediately after exposure to acceleration, the quantity of pancreatic juice was found to be directly dependent on the initial functional level of the

gland: some dogs, after the first exposure, showed a drop in juice secretion; while others had increases. Later on, all the experimental animals showed an increase in secretion, but the fluctuation in the amounts of juice secreted were phasic in nature (S. A. Bugrov).

In the gastric, pancreatic, and intestinal juice of these same dogs, studies were also made of the lysozyme activity (the experiments of S. A. Bugrov, M. I. Kozar', and V. Ye. Potkin); its dynamics differed from the dynamics of the other enzymes studied: the quantity of lysozyme decreased sharply and the after-effect period lasted for 4 to 6 weeks (M. I. Kozar'). The established decrease in lysozyme activity is obviously connected with the total decrease in the immunological resistance of the organism as a result of the extremal exposure. Here, we are speaking not only of the weakening of the antibacterial properties of the digestive juices, but also the immunochemical changes in the internal environment of the organism. Lysozyme was also found to be an indicator of the reactivity of the organism in a study of the effect of a number of other factors (changes in the gaseous environment, hypodynamia, etc.). For practical purposes, the determination of lysozyme activity is performed in the saliva. After a single exposure to acceleration or other environmental factors, the lysozyme activity of the saliva returned to the initial values over a 1-day period; that of the gastric juice after 28 days; that of the pancreatic juice after 6 to 7 weeks, and that of the intestinal juice over a period of 3 months. /19

The results of histophysiological studies have shown that the changes in the secretory and motor activities of the gastrointestinal organs are combined with pathomorphological disturbances of the various tissue structures of not only the alimentary but of the other systems of the body as well (Ye. F. Kotovskiy; M. I. Razumov and M. I. Khazen).

Thus, in order to judge the functional state of the organism and its course of adaptation to high-gravity exposure, as well as to other extreme stimuli, consideration should be given to all the after-effect reactions of those functional systems, including also the notion of latent effects resulting from exposure to tension against the background of an over-all state of the organism which is outwardly satisfactory. When such an approach is used, it should be possible to judge the regular patterns of the course of the complex adaptative and compensatory processes which are determined by the unity of the structure and function of the entire organism. The impairment of this unity is the most direct road to pathology. Our studies have shown that these or other impairments in the organs of the gastrointestinal tract during acceleration and hypoxia are, much like those noted during some other extremal exposures, e.g., explosive decompression, capable of being smoothed-over considerably when definite intervals are present between repeated exposures to one and the same stimulus.

A very effective means of preventing the above-mentioned borderline-pathology in the alimentary system is also alpine training in combination with a rational diet. When the correct theoretical approach is used, it may be possible to forecast the course of the physiological processes and guide them so

as to support the homeostatic functions of the organism and thereby work-capacity and health.

It is natural that a deep study of the activity of the gastrointestinal organs with reference to prolonged space flight will make it possible to come closer to perfection in the principles of constructing the physiological and biochemical bases of human diet under these conditions.

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PROBLEMS OF CREATING LIFE SUPPORT SYSTEMS FOR SPACECRAFT

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ABSTRACT. This paper discusses the main problems related to life-support systems for spacecraft. Their quality will determine the health and performance of the crew and, consequently, the fulfillment of the mission. Some advanced life-support systems are outlined and approaches in current research that may help to solve the problems are presented. It is shown that these problems can be solved on the basis of the combined efforts of specialists in medicine, biology, chemistry, and engineering.

The achievement of prolonged interplanetary flights poses a number of new and very difficult tasks for space biology and medicine. /20

In conjunction with this, in the opinion of Soviet and foreign scientists, the problem arises of creating long-acting complexes of life support systems for the space-ship crews (Yu. M. Volynkin and P. P. Saksonov; G. I. Veronin et al.; A. M. Genin; B. L. Gol'dshvend et al.; N. M. Sisakyan et al.; Ye. Ya. Shepelev; Talbot).

It is understood that within the framework of a brief article it will be possible to examine only a few of the most significant aspects of this problem.

The activity of a space-ship crew includes obtaining, accumulating, and transmitting various data of a scientific and technical nature; supporting the operation of the ship's systems and controlling the ship; and self-servicing, including servicing the complex of life-support systems which, in the final analysis, supports the crew itself.

The latter type of activity, while useful per se, obviously cannot be classified in the "useful" category from the viewpoint of the goals of the expedition, since any increase in the amount of time spent on self-servicing (including servicing the life-support systems) decreases proportionally the amount of time which may be used for conducting scientific experiments and carrying out the program of the flight.

From the functional viewpoint, the task of a life-support system complex may be formulated as the creation and maintenance of environmental conditions within the living and working sections of the spacecraft for the entire period of the flight or expedition which will ensure the following for the crew:

- a working capacity sufficient for carrying out the tasks assigned, and
- a minimal probability of the occurrence of pathological changes within the human organism.

The complex of life-support systems may provide for the realization of the following functions:

1. A decrease in the degree or probability of the exposure of humans to the unfavorable external factors of outer space: vacuum, meteorites, penetrating radiation, weightlessness, etc. (Yu. M. Volynkin and P. P. Saksonov; A. V. Lebedinskiy and Yu. G. Nefedov; Talbot), by creating a shell around the working and living sections, special anti-meteorite and radiation shields, drugs for decreasing the effects of radiation exposure, methods of compensating for the absence of the effects of gravitation, etc.

2. Supplying the crew with the substances and energy necessary for vital activity: food, water, light, oxygen, etc. (A. M. Genin, V. V. Levashov; V. V. Olizarov; Richards et al.) by means of reserves of the needed products and also by regeneration systems using the waste products of vital activity.

3. Removal of the products of human activity and the harmful substances released during the operation of the systems and equipment of the ship by cleansing the atmosphere of harmful impurities and microbial flora, air conditioning, means of sanitation and hygiene including sanitary equipment, etc.

4. Meeting human requirements for motion, rest, external information, normal conditions of work, etc. through a varied inventory of athletic equipment, the proper furnishings, means of communication, literature, motion pictures, creation of the proper interior, and in the organization of the work site, ensuring sufficient cabin space, etc.

5. Medical control over the state of health of the crew and maintaining it at the necessary level will be achieved by a space-physician using special medical equipment and drugs. /22

Life-support systems may be thought of as devices which must maintain the material and energy flows passing through man within the permissible range.

Since there is a connection between the magnitude of the flow and the variety of the potentials it evokes, it must be taken into consideration that between the environment and the human organism there must likewise exist a variety of potentials wherein the role of the environmental potential during the establishment of the substance flow is played by the concentration of these substances in the O_2, CO_2, CO, and other components of the atmosphere, as well as the concentration of impurities in the water.

The totality of flow and concentration values also makes up the conditions for human vital activity.

The table gives the average values of some conditions (flows and concentrations in the environment) which may be taken as the nominal ones for a prolonged stay by a human in the cabin of a spacecraft.

This model, to be sure, has been considerably simplified, but it does help illustrate the fact that in the enclosed space of a spaceship, man cannot be considered merely as a consumer of oxygen and food products.

"NOMINAL" CONDITIONS OF HUMAN VITAL ACTIVITY DURING PROLONGED SPACE EXPERIMENTS.

Food and water ration (in g/day)				Calories (in kcal./day
Proteins	Fats	Carbohydrates	Water	
130	120	400	2,200	2800-3000

Oxygen Requirements
780 g/day

Basic Excretions (in g/day)

Water Vapor	Carbon dioxide gas	Solid and liquid wastes
1,100	995	1,535

Atmospheric conditions in the cabin

Microclimate		Harmful Impurities (in mg/l)	
Temperature (in °C)	18	Carbon monoxide	0.002
Relative humidity	50	Amines	0.002
Carbon dioxide (in mm Hg)	2-3	Ketones	0.0003
Oxygen (in mm Hg)	160	Mercaptans	0.001
Nitrogen (in mm Hg)	600	Aldehydes	0.0005
Pressure (in mm Hg)	760	Alcohols	0.02

The influence of man on the formation of his environment must also be taken into consideration. It is this very change in the interrelationships between man and environment which has created the close connection between the medical and technical questions, between medicine and technology, in the matter of creating life-support systems.

Obviously, any medical study requires technical embodiments, and any of the life-support systems requires medical testing. The quality of the life-support systems affects the working-capacity and the state of health of the crew. The crew's working-capacity, in turn, may have a substantial effect on /23

the working-capacity of the life-support systems inasmuch as they must be serviced and controlled by man.

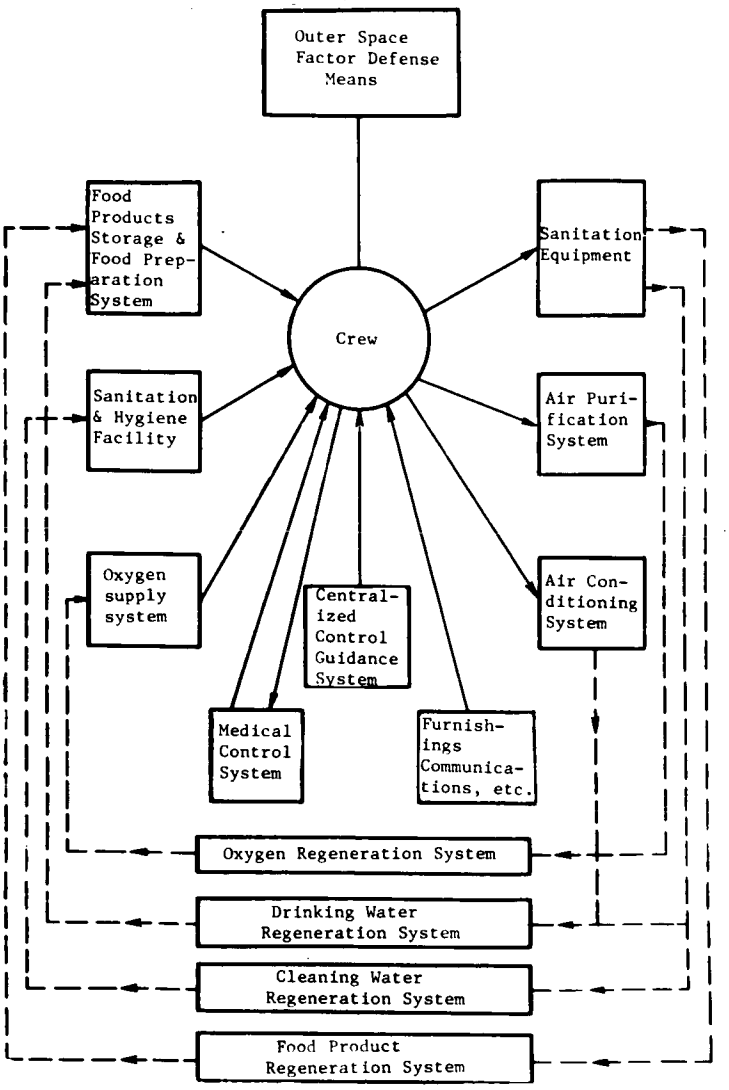

Figure 1. Functional Diagram of a Life-Support System Complex.

In other words, the complex of life-support systems must be characterized by a very complex interdependence between man and the systems making up the complex (A. M. Genin; B. L. Gol'dshvend et al.; Ye. Ya. Shepelev; Konecci).

The functional structure of the complex of life-support systems and the nature of the connections between the principal systems are illustrated schematically in Figure 1.

Depending on their purpose and the advisability of their use in a concrete case, these or other regeneration systems may not be included in the complex. Therefore, their connections with other systems are shown by dotted lines.

It is essential that a centralized system of control and guidance of greater or lesser complexity and degree of centralization be placed over the complex of life-support systems.

Each of the systems may be based on different technological processes.

For example, the oxygen regeneration system may use either the direct decomposition of CO_2 into C and O_2 and the electrolysis of a part of the metabolic water (after purification) excreted by man, or the Sabatier (Bosh) reaction for obtaining water from CO_2 and H_2 with subsequent electrolysis of the water. The hydrogen obtained by electrolysis is used again for hydration of carbonic acid. The use of other methods of oxygen regeneration is possible.

The regeneration of water from urine may be based on the catalytic oxidation of organic impurities, or a process of electrodialysis, or other methods.

Reproduction of carbohydrates as components of the diet can be done either by artificial synthesis from CO_2 and other products of human vital activity or by using a chain of higher plants with preliminary mineralization of the products of human vital activity or by using a chain of higher plants with preliminary mineralization of the products mentioned.

In each of these systems, in addition to the basic process, a number of auxiliary processes must be achieved. Into the composition of the system, besides the basic aggregate, go the auxiliary units and aggregates including ventilators, pumps, valves, pipe-conduits, etc.

The complexity of the systems and connections between them makes the development of a sufficiently well-founded classification of life-support system complexes very difficult.

One of the alternatives by which it might be possible to break up the systems into classes is flight duration time.

The type of process taking place within the system is a second alternative. This refers to systems using only physico-chemical processes and those using, besides physico-chemical processes, biological regeneration processes.

When one speaks of the selection of a complex of life-support systems for concrete application, this implies the determination of:

- the average requirements of the crew which will be satisfied and also the degree to which they will be satisfied;
- the average type and amount of storable products and regenerable products;
- the average type of technological processes which will be realized within the complex;
- the characteristics of the operation of the technological processes.

The solution of the problems enumerated above presumes taking into consideration a large number of factors such as weight of the complex, electrical and thermal energy requirements, heat-disposal systems (on a known level of temperature), reliability, ease of use, functional duration, etc.

As a criterion which summarizes all these indices, it is natural to use the weight of the complex together with all the auxiliary elements which service it. One must consider all sources of thermal and electrical energy, spare parts, instruments and apparatus for servicing, expendable substances, etc.

When other conditions are equal, the system with the lowest weight must be considered the better one.

This criterion may be minimized even when there are limitations imposed on the complex by the concrete conditions of its use. For example, on a given space-ship, limited power may be used for the demands of life-support, or a /25

limit is imposed on the size of the radiator surface for the disposal of waste heat.

In this case, out of a multitude of possible variants in the complex, the variant with the minimal weight is chosen in which the power requirements or radiator surface do not exceed the set values.

It must be mentioned that the advisability of finding the optimal variant for an individual system in each concrete case must be very well founded.

The optimization of one system or group of systems is advisable only under the condition that the change in the structures or operation of the technological processes within them will not have a significant effect on the weight characteristics of the remaining systems of the complex. Sometimes, having achieved a weight-saving in one system, it is possible to lose more due to the increase in weight of the remaining systems.

Currently, there is no convincing proof that the criterion being used is the best. Other factors should probably be introduced into the criterion such as the measured working capacity of the crew, the duration of the expedition and the cost characteristics where possible.

Increasing the duration of flights and expeditions and the continually increasing distance of the ship from the supply bases obviously presents even more rigid requirements as to reliability and autonomy of the life-support systems, decreasing the expenditure of stored materials, and increasing the degree of self-sufficiency of the complex in materials. The possibilities of developing life-support systems in these directions are shown in Figure 2.

It is evident from Figure 2 in particular that the decrease in reserves of expendable materials must be paid for by increasing the quantity of energy required by the life-support systems per unit of time.

The reliability of life-support systems designed for long-term operation /26
is a very broad concept taking into account their stability, the probability of unfailing operation over the time assigned, the allotment of time for repair in case of breakdown, and a great number of other reliability criteria.

According to these characteristics, systems based only on physico-chemical processes are currently more reliable than those including biological processes.

A typical diagram of a complex of life-support systems based on physico-chemical processes is shown in Figure 3.

This complex, using water electrolysis, CO_2 reduction to methane and water, physico-chemical regeneration of water from condensates and urine, and also reserves of food products, permits a reserve of expendable substances per man to be achieved which does not exceed 1 kg/day.

Systems with biological linis are more sensitive to the external factors of flight and are less stable in terms of departure characteristics. They are heavier and their use becomes rational only when a very long flight is planned.

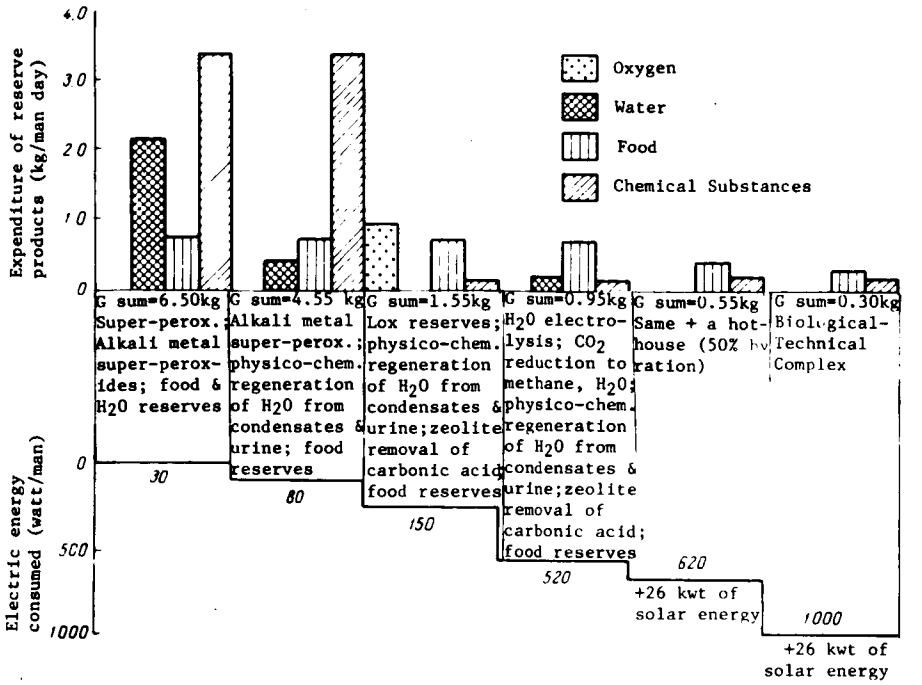
Expenditure of reserve products (kg/man day)
4.0
3.0
2.0
1.0
0
Oxygen
Water
Food
Chemical Substances
G sum=6.50kg Super-perox.; Alkali metal super-perox-ides; food & H2O reserves
G sum=4.55 kg Alkali metal super-perox.; physico-chem. regeneration of H2O from condensates & urine; food reserves
G sum=1.55kg Lox reserves; physico-chem. regeneration of H2O from condensates & urine; zeolite removal of carbonic acid; food reserves
G sum=0.95kg H2O electro-lysis; CO2 reduction to methane, H2O; physico-chem. regeneration of H2O from condensates & urine; zeolite removal of carbonic acid; food reserves
G sum=0.55kg Same + a hot-house (50% ration)
G sum=0.30kg Biological-Technical Complex
Electric energy consumed (watt/man)
0
500
1000
30
80
150
520
620
+26 kwt of solar energy
1000
+26 kwt of solar energy

Figure 2. Prospects for the Development of Life-Support Systems.

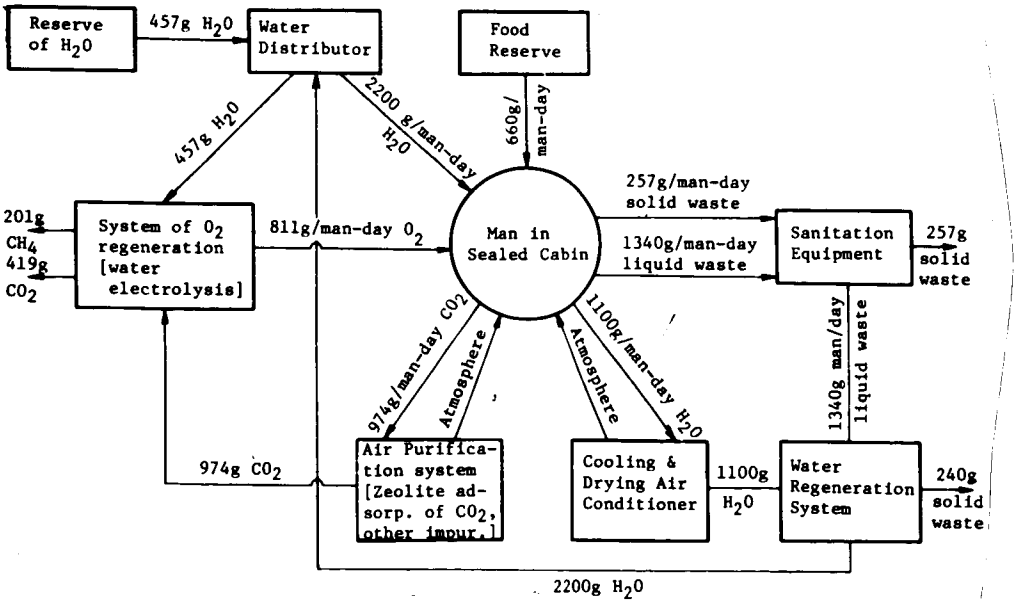

Figure 3. Theoretical Diagram of one of the Possible Variants of a Complex of Life Support Systems Using Only Physico-Chemical Processes of Oxygen and Water Regeneration and Having Good Product Reserves.

Considering this, in the immediate future it will be advisable to give preference to the development of complexes of life-support systems using only physico-chemical processes, including small biological links in them for purposes of pure research only. Undoubtedly, it will be necessary at the same time to continue to study the characteristics of the biological processes and concrete possibilities of using biological links in the life-support systems in the later stages of the conquest of outer space.

Particular attention should be given to some special questions on the construction of life-support system complexes which can perform cycling of substances. A great deal depends on to what extent the correct paths for the solution of these problems are chosen. /27

The difficulty is that practical realization of substance cycling, even on a small scale of self-sufficiency of the complex in materials, invariably runs into significant problems which are determined by the multi-variability and interconnectedness of the systems and also by the insufficient level of our understanding of the processes in the separate systems.

The diagram shown in Figure 4 gives some idea of the complexity of the connections between the systems in a large complex.

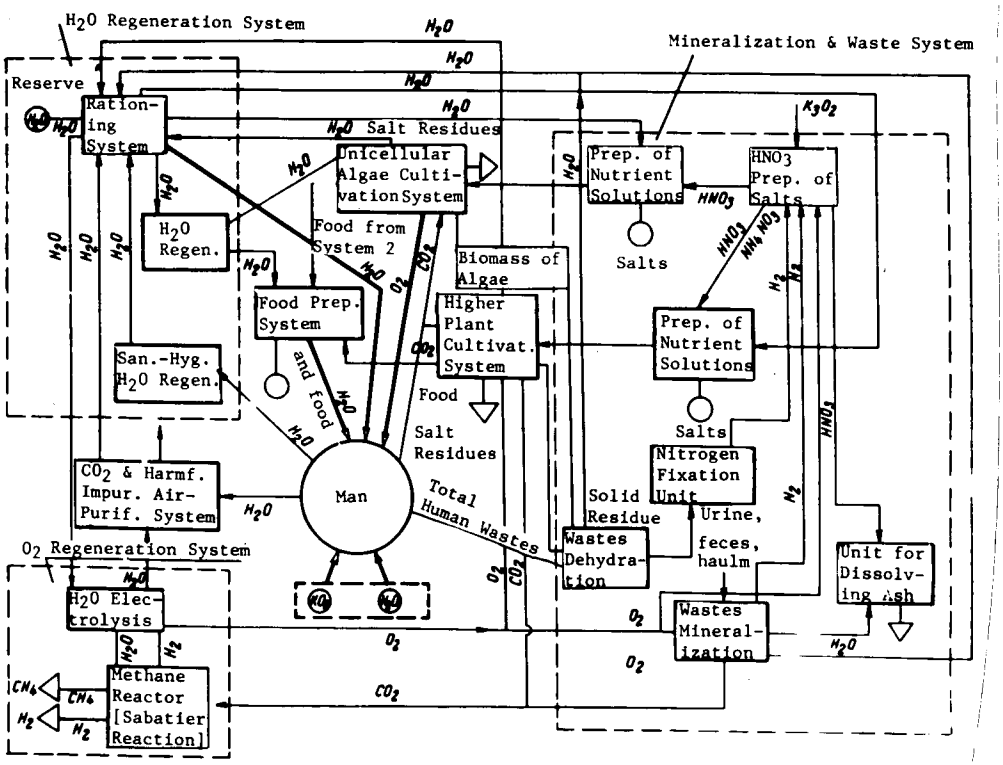

Figure 4. Theoretical Diagram of a Life-Support System Complex Using Biological Links for Reproducing Carbohydrates, Plant Proteins, and Regeneration of Part of the Oxygen and Water.

The factors enumerated above, and also the long duration over which life-support systems which use substance cycling must function, substantially complicate the theoretical analysis of the characteristics of the complexes; they also decrease the accuracy and reliability of the results.

The reaction of man to prolonged exposure to all the factors of the environment, the compatibility of the systems with each other and with man, the reliability of the systems, their control, the organization of crew activity during the expedition, and other knotty problems will be solved and disposed of only with the aid of very long-term experiments (Ye. Ya. Shepelev, Havens and Secord; Oswald et al.).

In order to perform such experiments under on-the-ground conditions, a special technical base is necessary which provides for the possibility of conducting tests of life-support system complexes of various types and structures with the participation of man.

At the same time that a preliminary analysis on paper permits a determination to be made as to which variants of life-support system complexes should be given experimental testing, and also for the study of which technological processes it is rational to spend money, prolonged ground experiments provide an opportunity for the practical study of the interaction of the systems and to obtain data clarifying a number of important characteristics of the complexes, thus permitting the transition to be made to the designing of flight systems. /28

In this connection, the tactics of the development of life-support systems for prolonged space flights, calculated in terms of many months and even years, is of particular importance.

At present, there is no way to come to a final conclusion as to the possibility of using one system or another for a spaceship except by complex testing with human participation conducted over a period of time corresponding to the projected duration of the space flight. It is completely natural that in the future, the organization of such tests will encounter great difficulties.

In industry, the method of type testing of machines and their separate units has justified itself. In this case, the article is subjected to tests lasting only 10-20% as long as the established duration of use at maximum power, capacity, temperature, etc. up to the point of complete destruction of the article. On the basis of statistical processing of the results of numerous tests, a conclusion is drawn as to the suitability of one or another item and a reliability coefficient for its operation is established.

A direct application of this method to the region of space biology and medicine is not possible for the following basic reasons:

- - it is not possible to obtain the necessary quantity of experimental data to be statistically processed in connection with the limited quantity of items of one type produced (in this case, life-support systems);

- - in conducting tests of this type (with the participation of man) which are applicable to a given flight duration, it is impossible to make a practical

evaluation of the factor of accumulation of harmful impurities and microbial flora, changes in the ionic composition of the atmosphere and water, changes caused by chronic radiation under the conditions of the flight, etc.

It is necessary to develop the proper method for medico-biological testing under the conditions determined by the supplementary loads and extremal situations, using the information-measuring complex which permits not only the establishment of the external characteristics of operation (changes in operation, going out of order) but also the revelation of the mechanism of one set of transformations or another caused by prolonged exposure to the factors of flight. It would be premature, however, to conclude that the necessary data are already available today for the development of techniques of long-term prediction. First of all, it will be necessary to accumulate enough experimental material on the prolonged stay of a man under the conditions of the unique environment of living in a hermetically sealed space; also the reaction of the organism must be studied from all sides and the boundaries of variability of the vital processes must be determined so that they may be guaranteed the necessary support.

Considering the complexity of the problem, some of the main tasks may be formulated, the development of which would accelerate the processes of study, development, and testing of life-support systems:

1. Study of the nature of crew activity and preliminary development of standard subprograms of this activity for spaceships of various purposes (F. D. Gorbod and M. A. Novikov; N. N. Gurovskiy et al.; L. L. Kakurin and Yu. N. Tokarev; Hibben, Richards et al.).

2. Study of the changes in work-capacity of man and his physiological reactions as functions of the conditions of the environment.

3. Substantiating standard criteria for the selection of variants of life-support system complexes.

4. Development of methods for the approximate evaluation of weight, energy, and other characteristics for the separate aggregates and systems depending on the type of technological processes in use.

5. Development of methods for constructing mathematical models of life-support system complexes and methods of optimizing them.

6. Development of methods for planning long-term experiments for the study of the interaction of life-support systems with each other and with man and the performance of similar types of experiments.

The factors mentioned above have far from exhausted all sides of the problem of creating life-support systems. However, even the cross-section of tasks listed shows how much yet remains to be done in this field.

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ORIGINAL ARTICLES. SPACE BIOLOGY

THE PROBLEM OF SPACECRAFT HABITABILITY

Yu. G. Nefedov and S. N. Zaloguyev

ABSTRACT. A formula is proposed for estimating the composition of the atmosphere in an enclosed space. Studies have indicated that the standards for maximum permissible levels of trace contaminants be based on maintaining a definite difference in the partial pressures of these contaminants in the exhaled air and the air of the sealed compartment. This will preclude accumulation of trace contaminants in the human body. Further studies should be concentrated on the biological compatibility of crew members in view of individual differences in human metabolism and microflora.

One of the pressing problems of space biology and medicine is to ensure /30
the habitability of the sealed cabins of spacecraft. This problem - the habitability of sealed compartments - first received recognition in connection with the development of submarine travel. The work of many scientists (D. Gorlov; Falcomata; Ellis; Ebersol) has shown that the successful use of submarines depends directly on the conditions of habitation within them.

It should be stressed that the problems of spacecraft and submarine habitability have much in common. In the first place, for both submarine and space travel, the creation and maintenance of favorable conditions in the surrounding air is of great significance. The significance of this very factor is often stressed by the term "air habitability." However, the solution of this problem in the spacecraft cabin is complicated by a number of considerations: limited energy sources for controlling the atmospheric composition; weightlessness affecting the state of aerosols, the particles of which will manifest a tendency to conglomerate and form larger aggregates (Schaefer), the constant effect of the heightened background ionizing radiation, etc.

One of the characteristic conditions of spaceship habitability is the fact that the crew members are compelled to remain in a hermetically sealed compartment of small volume for the duration of the entire flight.

A number of the specific environmental features of the sealed cabin depend on the operation of technical equipment, the construction of the ship, and factors peculiar to outer space; others arise as a result of the peculiar interrelation between man and the environment. Thus, the habitability of the spaceship cabin refers to the conditions of life and work of the ship's crew members, conditions created by the operation of various technical devices, the

construction features of the ship, the action of the factors of outer space, and the vital activity of man.

It is not possible to give a detailed rundown of all the problems of habitability within the limits of one article. In view of this fact, we will confine ourselves to some factors which, on the one hand, are the most specific for a spaceship cabin and, on the other hand, determine the essence of the environment of a hermetically sealed space of limited volume during its prolonged occupation by a man.

The data obtained when a large number of different types of chamber tests were performed convinced us of the fact that a very significant factor in the prolonged isolation of a human being in a sealed container is the change in the chemical composition of the gaseous environment. This is also indicated by the work of Rowlett and Lee; Hendel; Bovee and Schubert.

According to Weber's data, the increase in the level of harmful impurities in the atmosphere of the spacecraft cabin during long flights may follow a /31
linear law which makes it possible to some extent to forecast the possible concentration of these substances. In view of this fact, a further, more penetrating study of the dynamics of the levels of harmful impurities in the air, especially of the qualitative composition of the complex of organic substances which, according to our own and Schaefer's data, is the most important of all the admixtures mentioned, is currently of extreme importance. The most important part of the over-all problem of improving spacecraft cabin habitability is the search for methods of complete air purification.

Another very pressing question is that of the principles of hygienic assessment of the state of the gaseous environment of the spacecraft. It is perfectly clear that the general rules of industrial hygiene cannot be extended to sealed cabins in which man must work continuously for long periods. Despite the fact that the concentration of most of the harmful impurities (ammonia, amines, acetone, aldehydes, etc.) in the air of mock-up spacecraft cabins has generally not exceeded the established limits, it would be impossible, in our opinion, to give a favorable assessment to such conditions of "air habitability."

Most scientists (I. G. Fridlyand; I. G. Gel'man; B. M. Martsinovskiy; and others) are inclined to think that the various harmful impurities contained in the air in concentrations not exceeding the maximum permissible levels exert a nonspecific action on the human organism. The simultaneous presence of several substances in the air may cause intensification of this nonspecific action. We encountered such phenomena in one experiment when, as the result of the complementary action of small concentrations of ethylacetate, a distinct gap was observed in the adaptive mechanisms developed earlier by the subjects.

Considering this, A. G. Aver'yanov et al., P. I. Bogatkov, and Yu. G. Nefedov have suggested that the state of the atmosphere in a sealed cabin be evaluated by the following equation:

$$\frac{X_1}{A_1} + \frac{X_2}{A_2} + \cdots + \frac{X_n}{A_n} \leqslant 1,$$

where X_1, X_2 ... X_n are the detected concentrations of the specific substances and A_1, A_2 ... A_n are the maximum permissible concentrations of these ingredients.

If the sum of the ratios does not exceed unity or is equal to it, then the sanitary state of the air should be considered satisfactory. It is quite obvious that this approach is not void of shortcomings and is somewhat schematic. Thus, for example, the formula proposed does not take into consideration the biological significance of the individual harmful impurities, the synchronous action of other environmental factors on the human organism, etc. All this notwithstanding, it must be conceded that this approach is more correct than an evaluation of the environment based on the concentration of each individual ingredient alone. Therefore, it may be used as a basis for computations when making plans for air purification systems for spaceship cabins.

Some scientists (Stokinger, cited by Hendel) have made an attempt to determine the maximum permissible level in a spaceship cabin by considering the action of a number of the factors of space flight, the over-all physical condition of the man, etc. However, in this case, the element of subjectivity is introduced into the quantitative evaluation of the factors, and this diminishes the value of the proposed formula considerably.

The principles for determining the maximum permissible levels of some harmful impurities for the conditions of prolonged and continuous habitation of a sealed cabin by man are also worthy of attention. The approach to establishing /32
these maximum permissible levels must be based on the premise that if the aerial environment becomes contaminated by the products of human vital activity which are predominantly or exclusively expelled from the body with the breath, then the level of these substances in the surrounding air must not exceed such concentrations which could cause a noticeable decrease in the partial-pressure differences (between the exhaled air and the air of the sealed compartment) and could thereby create the conditions necessary for their accumulation in the organism due to a decrease in their rate of excretion.

Reviewing the results of numerous studies conducted in the period 1956-65, we became convinced that the particular conditions of habitability in a sealed compartment are determined in many ways by the processes connected with the vital activity of man. Such an interrelationship is not observed under ordinary conditions.

The conditions of habitability in a hermetically sealed compartment of limited volume exert a tremendous influence on the character of the interrelationships between man and environment.

As an example, we could cite the experimental results shown in Tables 1 and 2.

Data on the changes in the bacterial flora merit particular attention. The stay of man in a sealed chamber is accompanied by a noticeable increase in the quantity of microorganisms on the skin and mucous membranes. In this connection, data on the possibility of intensifying the pathogenic properties of

microorganisms, and also the mutual exchange of these microorganisms between persons in a sealed cabin, are especially alarming. The degree of bacterial contamination of the air and objects in the cabin increases considerably. The interrelationship between the composition of the aerial microflora of sealed cabins and the autoflora of the human skin testifies to the fact that the chief source of environmental contamination is man. /33

As an example, we cite the data of Table 3 which shows the results of studies of the air microflora of a sealed chamber and that of the pharynx and skin of the subjects during a 120-day experiment.

TABLE 1. EXCRETION OF MOISTURE, AMINO COMPOUNDS, AND ORGANIC SUBSTANCES (ACCORDING TO OXIDIZABILITY) INTO THE AIR OF A SEALED CHAMBER IN EXPERIMENTS WITH DIFFERENT TEMPERATURE CONDITIONS

Average t° for the experiment	Moisture excretion (kg/man/day)	Amino compounds (g/man/day)	Organic substances (g of O_2/man/day)
10.1	1.34	0.083	0.084
2.02	1.27	0.094	0.134
31.4	2.18	0.251	0.257
43.8	7.60	0.441	0.804

TABLE 2. EXCRETION OF MOISTURE, AMINO COMPOUNDS, AND ORGANIC SUBSTANCES (ACCORDING TO OXIDIZABILITY) INTO THE AIR OF A SEALED CHAMBER IN EXPERIMENTS WITH LIVING CONDITIONS OF VARYING SEVERITY

Condition of the experiment	Moisture excretion (kg/man/day)	Amino compounds (g/man/day)	Organic substances (g O_2/man/day)
Average t° = 44.6.....	8.41	0.248	0.666
Average t° = 44.1, noise of 105 to 110 db.....	9.52	0.344	0.686
Average t = 44.3, gamma field with intensity of 4.2 μr/day.....	9.42	0.354	0.761
Average t = 43.8, noise of 105-100 db, gamma field with intensity of 4.2 μr/day.....	7.60	0.441	0.804

At the present time we do not have enough data to obtain a complete picture of the importance of quantitative and qualitative changes in the bacterial flora. However, the character of these changes leads one to consider them undesirable. During a prolonged stay by man in a sealed cabin, these changes can be an obstacle to the continuation of the space flight.

TABLE 3. MICROFLORA OF THE AIR, PHARYNX, AND SKIN OF SUBJECTS AFTER DIFFERENT PERIODS OF A 120-DAY EXPERIMENT (AVERAGE VALUES)

Indexes studied	Before the experiment	Periods of the experiment (days)								Periods after the experiment (days)		
		1-15	16-30	31-45	46-60	61-75	76-90	91-105	106-120	1-15	16-30	31-60
Total # of microbes per m^3 of air.....	1500	7500	12 000	14 000	7500	17 000	14 000	30 000	3000*	--	--	--
Total # of microbes per cm^2 of subjects' skin (abs.)....	30	56	66	66	60	53	53	66	30*	39	30	31
Total # of microbes per cm^3 of washings from pharynx of subjects (millions).....	34	66	74	37	10	102	58	168	33*	30	28	30

*The low level of microbial contamination on days 106-120 is related to the development and use of a microorganism-removing air-purification system in the sealed chamber.

In conjunction with the peculiarity of the environment in a sealed cabin, the development of reliable means for controlling both the level of chemically harmful impurities and the extent of bacterial pollution of the air takes on particular importance. Along with the quantitative characteristics, these control methods must ensure the detection of qualitative changes as well. Thus, in evaluating the sanitary-epidemiological state of the environment, besides establishing the over-all number of microbes in the air, the determination of the individual types of microorganisms, which make it possible to judge the shifts in the autoflora of the cosmonauts, is of great significance.

The unfavorable nature of the atmospheric changes may be aggravated by the acquisition of harmful impurities found in the air of the cabin and of new toxic properties under the influence of different types of cosmic radiation (Lagerwerff).

Under the influence of radiation, and also as the result of the probable interaction of substances, the formation of new, toxic compounds is possible (Schaefer). /34

Likewise, the probability of changes in the isotope composition of the air which may occur as a result of the action of the heavy compounds of cosmic radiation or when some oxygen sources are used cannot be excluded. It is known, for example, that the liquid oxygen produced commercially contains a noticeable excess of O_{18} (R. Bently).

Under the influence of radiation and a number of other factors, even the ionic composition of the air can be changed. Calculations have shown that the ionization of the air in the cabin of a spacecraft will always exceed its natural earth-bound level by two or three orders of magnitude. As experiments have shown, shifts in the aero-ion composition do have an effect on the human organism and may, on prolonged exposure, cause definite functional changes in the basic physiological systems (Yu. G. Nefedov et al.).

We are attempting to resolve the basic laws determining the interrelations of man and environment in a sealed compartment by means of concrete examples. The mutual interaction of organism and environment is shown very clearly by an analysis of the dynamics of carbon monoxide accumulation in the air of the cabin. It has been shown that when technical sources of CO are not present in the cabin, the air nevertheless becomes contaminated with CO and the source of contamination is man himself, in whose organism CO is formed by some biochemical transformations which are still not clearly understood (Sjostrand). Being excreted from the organism and accumulating in the air of the chamber, the CO causes the appearance of the initial symptoms of carbon-monoxide auto-intoxication due to a decrease in the partial-pressure difference between the exhaled air and the chamber air. The development of autointoxication may be judged by the appearance of carboxyhemoglobin in the blood and also by the occurrence of definite changes in the central nervous system. Such interrelations may also seem justified for other harmful impurities which are excreted through the lungs, particularly carbon dioxide. This circumstance has, it seems to us, great significance for an understanding of the essence of the interrelations

between the organism and its environment in a hermetically sealed compartment. In conjunction with this, it can be concluded that the cause of many physiological shifts may be autointoxication by the products of vital activity excreted by the lungs, which ordinarily are not accumulated in the environment, as occurred in the case examined.

The special relationship formed between environment and organism causes the occurrence, in the latter, of shifts characterizing a certain physiological reaction to the change in the conditions of existence. Most of the physiological shifts are undesirable in nature and may develop into pathological changes when the unfavorable factors of the environment are aggravated (A. V. Lebedinskiy et al.).

An analysis of the physiological changes, based on the results of a number of long-term chamber experiments (up to 120 days), has revealed the presence of phase-qualities in the changes in physiological functions.

The first phase is the initial reaction to the change in the conditions of existence; it is characterized by processes of readjustment in connection with the transition by the organism to the new functional level, corresponding to a certain extent to the altered conditions. It is quite natural that these /35
shifts depend primarily on the unique readjustment of the regulator mechanisms in general and the functions of the central nervous system in particular. The break in the customary stereotype is accompanied by certain changes in it, since in the concrete case the new conditions of existence to which the organism is compelled to adapt are unfavorable.

The completion of the readjustment process involves the normalization of many functions: sleep; motor reactions; light sensitivity of the eye; a decrease in the number of errors during work to the initial values, etc. Despite this, changes such as an increased tendency to become fatigued are retained. Therefore, adaptation is only relative, and to the extent that the unfavorable factors continue to act, impairment in the adaptation mechanisms continues and the phenomena of asthenization are revealed at the end of the tests.

The changes observed in the subjects upon emerging from the sealed cabin and switching back to normal life are worthy of special attention.

We have called these changes the "emergence" reaction. They are characterized chiefly by aggravated asthenization phenomena in which the asthenization has a tendency to be prolonged.

It should be emphasized that the transition to normal (earth) conditions of existence is achieved in a very brief time. Therefore, the less the conditions of the sealed cabin are distinguishable from ordinary conditions, the weaker will be the degree of the "emergence" reaction. The experience gained from one of these long tests has shown that the use of a complex of hygienic measures in the latter part of the test and the organization of a gradual transition of the subjects back to ordinary living conditions make it possible to decrease the extent and duration of the reactions mentioned.

Finally, the last problem to which we wanted to draw attention is one which we believe must be looked upon as one of the integral parts of the habitability problem. As has already been emphasized, the environment of a hermetically sealed space of limited volume designed for long-term human habitation is formed, to a considerable extent, as a result of the processes of human vital activity. Therefore, the individual differences in the metabolism of the crew members of the spaceship may cause contamination of the atmosphere by volatile impurities which are not characteristic of the separate individuals. In this respect, the individual differences in the automicroflora are also worthy of special attention. Experimental data have confirmed the possibility of an exchange between the personal autoflora of different persons under the specific conditions of living in a sealed cabin and a possible increase in the pathogenic properties of these microorgamisms.

These considerations permit us to suggest that one of the most pressing problems requiring solution in order to ensure the safety of prolonged space flights is the problem of "biological compatibility" of the crew members of the spacecraft. Naturally, the road toward the solution of these complex problems can only be outlined. However, even today, on the basis of the data available, it is apparently advisable to think of including, in the life-support system, elements which are capable of reducing the possibly unfavorable mutual interaction between the crew members to a minimum. Considering that such mutual interaction is realized primarily via the air, it is necessary to create the most favorable "air habitability" possible in the spacecraft by means of the complete elimination of harmful impurities and the normalization of the microbial flora.

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INCREASING THE RADIORESISTANCE OF THE POTATO UNDER CONDITIONS OF ANOXIA

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ABSTRACT. The paper presents a review of the literary data and the authors' findings relative to the utilization of the radioshielding effect of anoxia for plants growing in space greenhouses where they may be exposed to high doses of radiation. The results of experiments performed to study the radioshielding affect of anoxia, if any, when 1-mo-old potato seedlings were exposed to gamma rays are listed. When the doses were low (500 to 1500 rad) anoxia had little if any effect. Its radioshielding effect was very distinct when the doses were high (3000 to 5000 rad). The radioresistance of the potato plants was increased in the oxygen-free environment (nitrogen was substituted for oxygen). This was indicated by the increased potato yield from such plants.

At the present time, the possibility of using higher plants as one of the links in the life-support system of spacecraft is under study (N. M. Sisakyan et al.; Ye. Ya. Shepelev). /36

The potato, as a high-yield starchy plant, is one of the possible components of the space greenhouse (D. F. Gertsuskiy and V. M. Abramova et al.). However, calculations have shown that cosmic-radiation doses, particularly the protons of solar flares which can have an effect on biological objects during long flights, amount to tens of thousands of rad during the growth period of the plants (G. G. Bobkov et al.).

According to the latest studies (D. F. Gertsuskiy et al.), irradiation of the potato tuber (Khibinskiy variety) before planting, with gamma rays in a dose of 2000 rad or higher leads to a decrease in the number of developed plants and a drop in yield. When the potato is irradiated with 6000 rad, all the plants die.

It has long been established that the sensitivity of biological objects to ionizing radiation changes in relation to a number of external factors. The strongest effect on the effectiveness of ionizing radiation is exerted by the oxygen content in the tissues of the irradiated object and surrounding environment. /37

The experimental data available on the effect of oxygen testify to the fact that when different biological objects are irradiated under anoxic conditions, their radioresistance is increased 2 or 3 fold and more. Experiments of this

type have been conducted with plants, bacteria, insects, and animals (Ye. S. Shchepot'yeva et al.; V. M. Mikhel'son; Ehrenberg et al.; Nybom et al.; Konzak; Howard; Hornung et al.; A. Hollander et al.; Konecci and Taylor; Laser; I. M. Khazen et al.).

Vegetable organisms, as distinct from animals, can be kept for long periods in an oxygen-free environment without harm -- a fact making it possible to use anoxia as one of the most effective methods of protecting plants against ionizing radiation.

Starting with these considerations and attempting to make a practical approach to the solution of the problem of decreasing the harmful effect of ionizing radiation on plants, we conducted the current set of experiments on the radio protective effect of anoxia during irradiation of germinated potato tubers.

Data on similar work with the potato are lacking in the literature.

Technique

The potatoes (Khibinskiy variety) were placed in flat, hermetically sealable boxes of vinyl plastic and germinated in the light for 30 days. During this period the shoots attained 5 to 10 cm in height. When 30 days had elapsed half of the boxes with the sprouted tubers were sealed and their ordinary atmosphere was replaced by nitrogen. The air was first pumped out and then the nitrogen was introduced. To assure complete removal of the oxygen, this operation was repeated 10 times. In the other half of the boxes the sprouted tubers were left in an oxygen-containing environment. Eighteen hours after the ordinary atmosphere was replaced by nitrogen, irradiation of the potatoes was carried out and 2 hours later the seals were broken on the boxes. Thus, the potatoes had been under anoxic conditions for a total of 20 hours.

The potatoes in the nitrogen and oxygen atmospheres were irradiated with gamma-rays simultaneously using the EGO-20 at an intensity of 747 rad/min in doses of 500, 1500, 3000, and 5000 rad.

The control plants were sprouted potato tubers maintained under these same gas conditions but not subjected to irradiation.

The potatoes were planted in soil the day after being irradiated (June 29) on an experimental plot situated on the Moscow River delta. The soil was medium loam and well cultivated. The tubers were planted by marker with a distance of 70 x 50 cm between the plants. The experimental and control potatoes each occupied a single row (25 tubers in each).

The experiment was repeated 3 times. Thus, each variant of the experiment was represented by 75 plants.

During the growth period the experimental plot was constantly kept clean; the plants were each hilled twice. The potatoes were harvested on September 16.

Results of the Experiment

The effect of ionizing radiation was expressed in a delayed appearance of shoots and later growth of the tops, especially in the cases where the sprouting tuber had been irradiated in an oxygen environment. The leaves on such plants grew on shortened stalks; they were leathery and grew together somewhat. /38

The main criterion for evaluating the protective action of anoxia was the yield of tubers. These data are shown in Table 1. From the data listed here it is evident that for relatively small doses of radiation (500 to 1500 rad), the difference in yield between the variants is unreliable and not great. However at doses of 3000 and 5000, the protective effect of anoxia proved to be very substantial and reliable. At a radiation dose of 3000 rad the anoxia decreased the harmful action of the radiation by a factor of 4. Interpolated for 25 plants, it can be said that anoxia produced a two-fold increase in yield.

Of course, such a comparison can hardly be considered valid, since, when the radiation dosage was 3000 rad in an oxygen environment, more than half the tubers planted, in general, did not produce any yield. The decrease in the number of plants in this variant is undoubtedly the result of the action of radiation and not accidental death such as took place in the control variants.

Even more noticeable was the effect exerted by anoxia at a dose of 5000 rad. Not one of the oxygen-irradiated plants produced a yield of tubers, whereas 10 of the 25 plants irradiated in the oxygen-free environment formed tubers.

A similar radioprotective action of anoxia during high radiation doses has been noted by other scientists (V. V. Khvostova and K. A. El'shuni). /39

The starch and ascorbic acid levels were determined in the tubers of the harvested potatoes from all the experimental variants (Table 2).

The protective effect of anoxia also extended to the starch content: no decrease in starchiness with increase in radiation dose could be detected; rather, it was possible to note a tendency for it to be somewhat increased. Irradiation of the sprouting tubers in the oxygen environment produced some decrease in the production of ascorbic acid in the tubers. In the oxygen-free environment, this decrease was practically abolished. On the whole, the vitamin C level in the tubers of all the variants in our experiment was around 10 mg%, i.e., within the norm for potatoes (A. A. Pokrovskiy).

The results of these experiments show that the potato, much like other biological objects, can be damaged by ionizing radiation (gamma rays) but that this damaging effect is reduced if the irradiation is carried out in an oxygen-free environment. This provides a basis for the belief that future studies in this direction will reveal ways to raise the radioresistance of vegetable objects even further and to protect the plants in space greenhouses from death when the dose of ionizing radiation is increased, e.g., in case of solar flares.

TABLE 1. POTATO YIELD OBTAINED FROM TUBERS IRRADIATED WITH INCREASING DOSES OF GAMMA RAYS DURING GERMINATION

γ-ray dose in rad	Irradiation in an environment	Series I			Series II			Series III			Average					
		Plants collected	yield (g)		Plants collected	yield (g)		Plants collected	yield (g)		Plants collected	Yield from the plants collected (in g)	D/md		yield from 25 plants (in g)	D/md
			From the plants collected	From 25 plants		From the plants collected	From 25 plants		From the plants collected	From 25 plants			to oxygen	to nitrogen		to oxygen	to nitrogen
Control	oxygen	25	5 915	5 915	24	4 815	5 016	25	3 755	3 755	24.7	4 828	—	—	4 895	—	—
	nitrogen	23	4 620	5 023	23	4 555	4 950	22	3 690	4 200	22.7	4 288	—	—	4 724	—	—
500	oxygen	25	5 300	5 300	25	5 520	5 520	24	4 455	4 650	24.7	5 092	0.4	—	5 157	0.7	—
	nitrogen	23	4 873	5 298	22	4 570	5 205	15	2 345	3 900	20.0	3 929	2.3	0.7	4 801	0.3	0.2
1 500	oxygen	19	3 260	4 300	23	4 690	5 100	22	3 443	3 800	21.3	3 798	2.7	—	4 400	1.3	—
	nitrogen	22	3 085	3 500	22	4 605	2 500	25	2 715	2 715	23.0	3 469	3.5	2.1	3 805	2.8	2.4
3 000	oxygen	5	320	1 600	13	943	1 835	15	405	675	11.0	556	11.0	—	1 370	9.2	—
	nitrogen	21	2 105	2 500	19	2 690	3 550	19	1 935	2 550	19.7	2 243	6.0	5.3	2 867	5.3	4.5
5 000	oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	nitrogen	8	398	1 243	8	600	1 875	14	835	1 490	10.0	611	10.2	9.5	1 536	8.7	8.3
												mD=389			mD=386		

D = the difference between the comparable variants; mD = experimental error

TABLE 2. CONTENT OF STARCH AND ASCORBIC ACID IN POTATO TUBERS

Variant of experiment		starch %	ascorbic acid (mg%)
dose rays of γ (rad)	irradiation in an environment of		
Control	oxygen	20.6	11.3
	nitrogen	18.8	11.1
500	oxygen	16.2	11.7
	nitrogen	18.8	9.8
1500	oxygen	18.1	9.3
	nitrogen	20.0	10.1
3000	oxygen	14.4	7.6
	nitrogen	20.0	9.9
5000	oxygen	--	--
	nitrogen	22.0	9.9

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CHANGES IN THE HEART DURING HYPOXIA (AN EXPERIMENTAL MORPHOLOGICAL STUDY)

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ABSTRACT. A 14 day experiment on mice kept in a pressure chamber at 378 mm Hg showed that acclimatization to hypoxia increased the resistance of the test animals to acute hypoxia and radial acceleration. The test animals exhibited distinct changes of the myocardium and valves. The data obtained indicate that the increase in specific and nonspecific resistance produced by adaptation to hypoxia is no basis for the assertion that hypoxia acclimatization has a favorable effect on the human body.

The problem of the favorable effects of acclimatization to hypoxia on the /40
subsequent resistance of man and animals to oxygen starvation is being widely discussed in the current literature (N. N. Sirotinin; V. V. Parin et al.). However, in order to determine the most rational conditions of hypoxia training, it will be necessary to determine to what extent it is possible for the organism to adapt to oxygen deficiency without the appearance of some type of pathological changes in the organs and tissues. The purpose of the present paper was to study the structural and metabolic changes arising in the heart under the influence of prolonged hypoxic hypoxia. The work is justified by the fact that data in the literature on this problem are, in the first place, few in number and contradictory, and in the second place, deal chiefly with the effects of relatively short-term and severe hypoxia.

Methods and Materials

The experiments were conducted on 100 male mice of the BALB/c strain weighing around 20 g. The experimental group was composed of 60 mice which had been kept in a ventilated pressure chamber for 2 weeks at an atmospheric pressure of 378 mm Hg (corresponding to an altitude of 5500 m). The control group consisted of 40 mice kept at normal atmospheric pressure. After the experiment was completed some of the animals were killed. The hearts of 30 of the control mice were fixed in acetone at 4°C and embedded in paraffin. Serial sections of the hearts were stained with hematoxylin-cosin, picrofuschsin, alcyan blue, toluidine blue, azan according to Heidenhain, methyl green pyronine (control with ribonuclease), and by the PAS method (control with amylase), and impregnated with silver by the method of Foot. The remaining 10 experimental and 10 control hearts were frozen with dry ice immediately after sacrifice and then transferred to a cryostat where serial sections 15 microns thick were prepared at -15°C. (In this study, hearts of test and control animals were mounted on the same object-holders. As a result,

slices of equal thickness were obtained which later, during the performance of the histochemical tests, were incubated under identical conditions.) In the serial sections of the hearts, the activity of oxidative enzymes bound to nicotinamide-adenine-dinucleotide (NAD) [isocitric-dehydrogenase, alpha-glycerophosphate dehydrogenase, lactic dehydrogenase, alpha-ketoglutaric dehydrogenase, malic dehydrogenase, glutamic dehydrogenase (Rubinstein et al.; Kh. N. Kul'tas), and inosinic dehydrogenase (I. V. Krasnov, 1965)] and of the enzymes bound to nicotinamide-adenine-dinucleotide phosphate (NADP) [glucose-6-phosphate dehydrogenase and decarboxylating malate dehydrogenase (Wegmann and Gerzeli; I. B. Krasnov, 1967)] were determined as well as that of alpha-glycerophosphate dehydrogenase not bound to NAD (Wattenberg and Leong) and succinic dehydrogenase (Nachlas et al.). Part of the sections prepared in the cryostat were fixed with formalin and stained with hematoxylin-eosin. /41

In addition, the red blood indexes (hemoglobin content and number of erythrocytes) were determined for a portion of the control and test animals, and the resistance to acute hypoxia and the action of radial acceleration were investigated.

Results and Discussion

During the 2-week stay of the mice in the pressure chamber at the low (378 mm Hg) atmospheric pressure, no deaths were observed. All the mice appeared outwardly to be in perfect health after the experiment ended, and only lagged slightly in weight when compared to the control group. Thus, the average weight of the control mice was 24.2 ± 0.38 g and that of the test mice, 19.9 ± 1.4 g ($P < 0.01$).

Histological and histochemical studies revealed that the control animals had no changes in their hearts whereas, 36 of 40 mice of the test group showed pronounced changes of varying degree, involving both the valvular apparatus and the myocardium. In the heart valves (usually the mitral and aortic valves were affected), a picture of "mucoid swelling" could be observed, this being the result of disorganization of the valve connective tissue. In such cases, the ground substance of the connective tissue revealed liberation and redistribution of the acid and neutral mucopolysaccharides (MPS) which are its components, along with simultaneous hydration and swelling. The increased water level in the vascular tissues was caused by the pronounced hydrophilic properties of the acid mucopolysaccharides liberated during the disorganization of the ground substance (A. I. Strukov, A. G. Beglaryan). As a result of this connective-tissue disorganization, the localization of the acid and neutral MPS, usually distributed throughout the heart valves of the normal animal in the form of a distinct network, was altered; their reticular distribution disappeared and was replaced by focal or diffuse accumulations of MPS in the valvular tissues, appearing as poured or punctate metachromatic staining in the histological sections (Figure 1, a and b). The content of acid MPS in the valves was somewhat decreased, apparently as the result of dilution or washing out by edema fluid (G. L. Myagkaya). Simultaneously with this, the intensity of the staining of the valves by the PAS method increased (Figure 1, c and d) - a fact which may be explained by the emergence into the tissues of blood glucoproteins or (more probably) by the liberation of the local neutral MPS during the disorganization

of the ground substance (G. V. Orlovskaya, 1960). Hydration and swelling were observed not only in the interstitial substance but also in the fibrous structures of the valve connective tissue, due to which the latter proved to be greatly thickened and was intensively impregnated with silver (Figure 1, e and f). /42

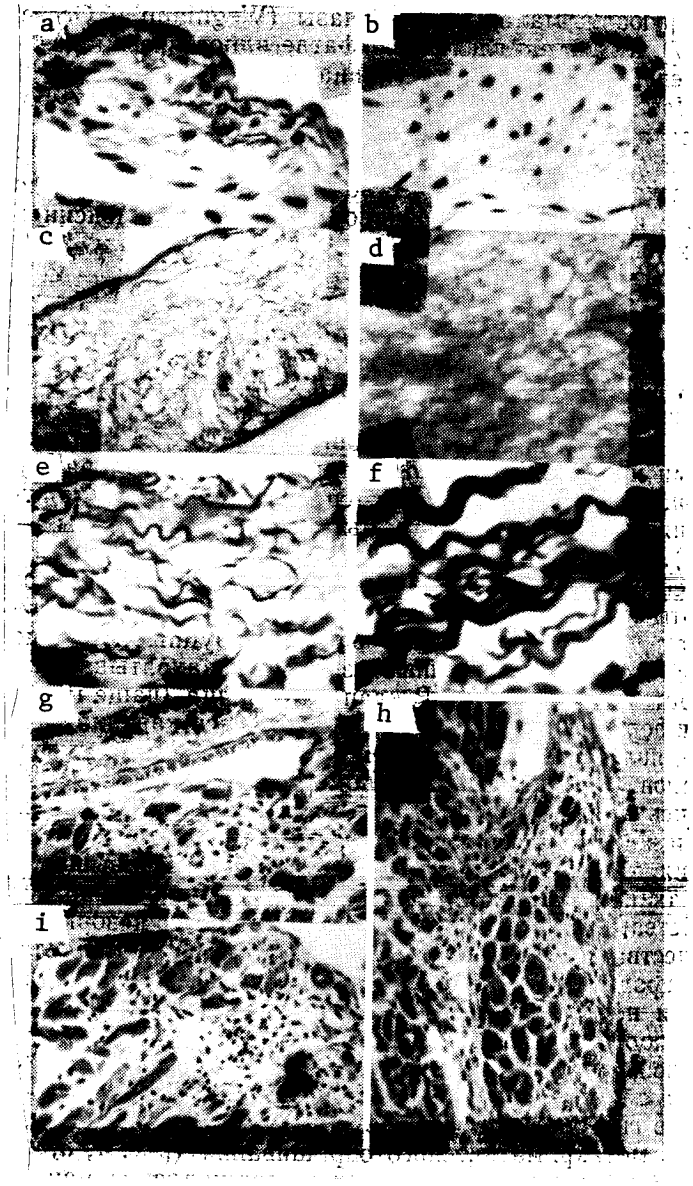

Figure 1. Acid mucopolysaccharides (grey-black) in the ground substance of the mitral valve of the heart of a healthy mouse (a); "mucoid swelling" of the ground substance of the mitral valve of a mouse after hypoxia (b); (stained with toluidine blue, 420 X).

Neutral mucopolysaccharides (grey-black) in the ground substance of the mitral valve of a healthy mouse (c); accumulation and redistribution of neutral mucopolysaccharides in the ground substance of the mitral valve of a mouse after hypoxia (d). (PAS method, 420 X).

Argyrophilic fibers in the mitral valve of a healthy mouse (e); and of a mouse after being under hypoxic conditions (f); swelling of the fibers is visible. (Silver impregnation by the method of Foot, 420 X).

Foci of developing sclerosis in the myocardium of a mouse after hypoxia, near the vessel (g); in the myocardial layer (h); in the papillary muscle and under the endocardium (i). (Stained with hematoxylin-eosin, 420 X).

Changes similar to those observed in the valves were also noted in the chondroid tissue of the valvular ring and in the walls of the individual major arteries; however, in the latter, they were less pronounced. It should be noted that the changes described above can be united under the concept of "mucoid swelling" according to the current definition of the term (G. V. Orlovskaya, 1958; A. I. Strukov and A. G. Beglaryan), and are reversible so that the normal structure of the connective tissue may be fully restored after cessation of the action of the harmful agent.

Besides the changes cited in the chondroid tissue, rather large necrotic foci were encountered at the base of the aortic valves and also in the muscle tissue attached to them; these were being replaced by young connective tissue. In these foci, along with the proliferating histiocytic and fibroblastic elements, there were a considerable number of neutrophils, and nuclear detritus. In one case the necrotic focus encompassed the aortic wall, in the lumen of which perimural thrombus formation was observed. /43

In the myocardium of most of the mice, multiple and individual sclerotic foci, large and small, were encountered arising in the area of necrosis of the muscle fibers. These foci had a tendency to be localized near the vessels and were usually encountered in the wall of the right ventricle, left auricle, the septum, and the subendocardial sections of the myocardium (Figure 1, g, h, i). Depending on the duration of the existence of such a focus in the developing connective tissue, there was a predominance of proliferating cells of the histiocytic type with an admixture of individual neutrophils or fibroblasts. Mature collagen fibers were not found in the sclerotic foci, indicating the relatively recent time of appearance of the foci since, according to the data available, 10 or more days are necessary for the development of mature collagen fibers. In a number of cases, individual undamaged or decaying muscle fibers were encountered among the developing connective tissues in the myocardium in the necrotic foci. On separate sections of the myocardium, a number of the animals showed evidence of diffuse proliferation of the connective-tissue elements of the stroma.

The activity of all the enzymes studied (excluding the non-NAD bound alpha-glycerophosphate dehydrogenase, which was not detected in the heart) in the connective-tissue elements fluctuated rather strongly in the necrotic foci, the greatest variation in activity being observed in the NAD-bound enzymes.

The level of succinic dehydrogenase activity and also the activity of the NADP-bound enzymes in the connective-tissue cells was low, and a higher activity was noted only in individual cells (Figure 2).

It is difficult to evaluate the type of connective-tissue cells in histochemical preparations, but since histiocytes or fibroblasts were predominant in the foci of developing sclerosis, it may be assumed that the highest level of oxidative enzyme activity (especially NAD-bound enzymes) was specific for these very cells. In the dystrophic or decaying muscular fibers encountered in the necrotic foci, when compared with the undamaged muscle fibers, there was increased activity of all the studied enzymes bound to NAD and NADP along with a decrease in succinic dehydrogenase activity.

A comparison of the data obtained with the results of the histological experiments performed previously by other authors (Yu. M. Lazovskiy; N. V. Balanina; Dalton et al.; Highman and Altland; Busnengo and Paolucci) shows that during prolonged continuous maintenance of mice under conditions of hypoxia, heart damage is more likely to occur at lesser degrees of atmospheric rarefaction than it would during brief but more severe hypoxic exposures.

Summarizing all the data given above, we may say that when mice are kept continuously for 2 weeks in a pressure chamber at 378 mm Hg, changes develop in

the hearts of such animals which encompass both the valvular apparatus and the myocardium. These changes have a dual character: some (valve damage) are reversible; others (myocardial damage) are irreversible and lead to the development of focal cardiosclerosis.

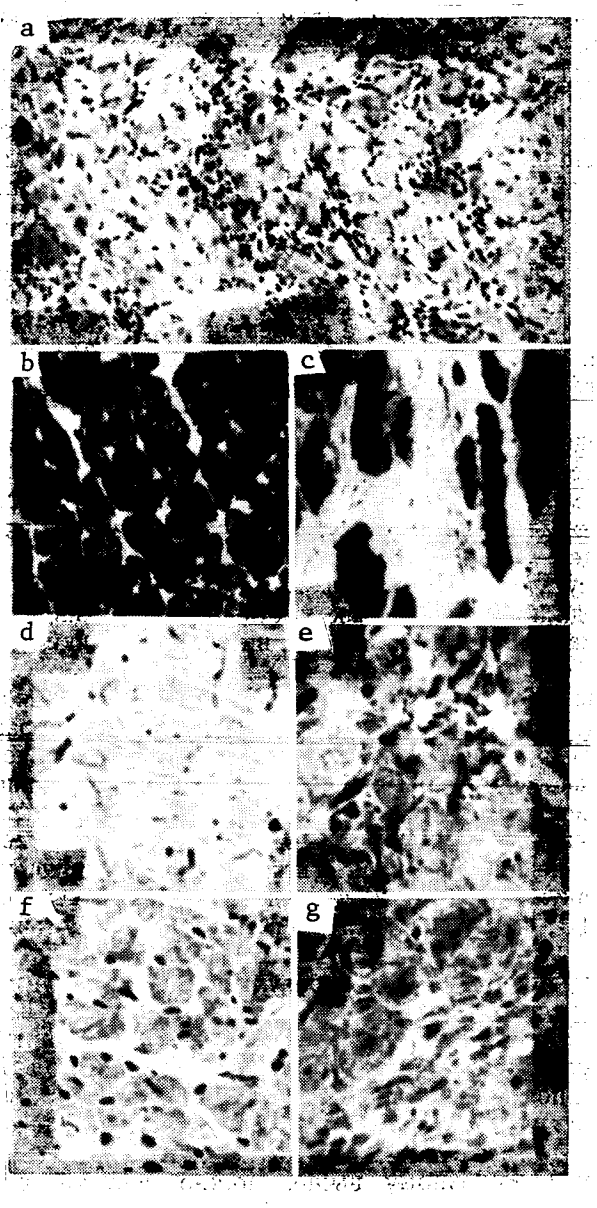

Figure 2. Focal damage to the muscle fibers and pronounced proliferation of connective-tissue elements in the myocardium (a). (Stained with hematoxylin-eosin, 70 X).

Distribution of succinic dehydrogenase activity (b); lactic dehydrogenase activity (d); and glucose-6-phosphate dehydrogenase activity (f); in the undamaged section of the myocardium. (420 X).

Distribution of succinic dehydrogenase activity in the focus of myocardial damage: low enzyme activity in the connective-tissue elements and decaying muscle fibers (arrow) (c). (420 X).

Distribution of lactic dehydrogenase activity (e) and glucose-6-phosphate dehydrogenase activity (g) in the focus of myocardial damage; increased enzymatic activity in the muscle fibers; high lactic dehydrogenase activity and low glucose-6-phosphate dehydrogenase activity in the connective-tissue cells. (420 X).

The results of physiological studies have shown that after a stay at an "altitude of 5500 m," the mice develop characteristic symptoms indicating adaptation to hypoxic hypoxia. The blood of the test animals was found to have an /44
increased content of hemoglobin (by 15 to 20%) and increased numbers of erythrocytes. A study of the resistance of the experimental mice to acute hypoxia by determining the value of the "ceiling altitude" as they were taken up in the pressure chamber "to an altitude of 9000 m" showed a distinct increase in this resistance in the animals who had been kept in the chamber "at 5500 m" for 2

weeks. The mice adapted to hypoxia were also noted to have undergone some increase in their resistance to radial acceleration.

Thus, after acclimatization to decreased barometric pressure, the mice had an increased resistance to acute hypoxic effects and to radial accelerations of great magnitude, along with distinct pathomorphological changes in the heart. The data obtained testify to the fact that an increase in specific and nonspecific resistance cannot be an adequate criterion for passing a broad biological judgment as to the favorable effect of acclimatization to hypoxia on /45
the organism. Great caution must be used in recommending the various types of acclimatization for astronautic practice.

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NEURO REFLEX MECHANISMS CONTROLLING HEMODYNAMIC SHIFTS DURING RAPID AND SLOW INCREMENTS IN ACCELERATION

Ye. B. Shul'zhenko

ABSTRACT. Anesthetized dogs were exposed to transverse (chest-to-back) accelerations of 9 G for 1 min. They were studied for hemodynamic changes in the cases of intact and denervated zones of the carotid sinus. It is concluded that slowly increasing accelerations play an important role in the development of adaptive and compensatory reactions and are of significance for the body tolerance to accelerations.

The resistance of the organism to acceleration is closely related to the direction of the acceleration vector with respect to the axis of the body, as well as to the magnitude and duration of exposure (P. K. Isakov and R. A. Stasevich). Another important factor is the period during which acceleration is attained. /45

We have studied the effect of this factor by studying the functional state of the cardiovascular system of animals with intact and denervated sinocarotid zones.

Technique

Experiments were performed on 2 groups of dogs (12 in each group) weighing 10 to 15 kg under morphine-chloralose-nembutal anesthesia. Catheters were introduced into the left ventricle through the left carotid artery and into the aorta through the femoral artery.

Arterial pressure was recorded on the ELEMA physiograph using tensometric pickup units rigidly attached to the seat of the centrifuge. The following parameters were determined: systolic frequency, systolic pressure in the left ventricle, and systolic, diastolic, pulse, and average pressure during systole in the aorta. The cardiac output and peripheral resistance were computed by the method of Maxwell (Maxwell and Cordell). /46

The animals of both groups were subjected to the action of a smooth, transversely directed, acceleration of 9 G for 1 minute. The increment time for this acceleration was 30 seconds for the first group of animals and 3-1/2 minutes for the second group. Dogs of each group were exposed to acceleration twice: first with intact sinocarotid zones, and then after these had been bilaterally denervated.

Results of the Study

When an acceleration of 9 G was reached in 30 seconds, a speedup in the rate of cardiac contractions was noted in the intact animals, along with a

decrease in vessel tone and an increase in cardiac output. Changes in arterial pressure were phasic: while decreasing at the beginning, the arterial pressure had exceeded its initial level somewhat by the end of the period of excess gravity, reaching its maximum value at the first minute after the centrifuge was stopped (Figure 1, Table 1). (The pulse pressure was an exception; its magnitude decreased over the entire exposure period -- at the beginning as a result of the sharper drop in systolic pressure in the aorta and at the end because of the greater increase in diastolic pressure in comparison with systolic pressure).

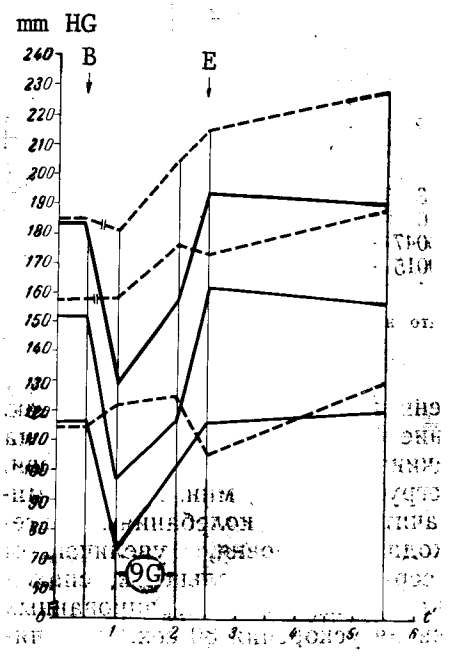

Figure 1. Changes in the Blood Pressure in Intact Animals at an Acceleration of 9 G. Conditions: Time for Attaining Maximal Acceleration: Solid Line 30 Sec., Dotted Line 3-1/2 Min.

Legend (Top to Bottom): systolic pressure in the aorta, diastolic pressure in the aorta; B = beginning, E = end of exposure

When the same acceleration was reached in 3-1/2 minutes, the hemodynamic shifts were characterized by an increase in all the arterial-pressure parameters for the duration of exposure, and by a speedup in cardiac activity, increased vessel tone, and slight fluctuations in cardiac output. After the centrifuge stopped, the hemodynamic indices gradually approached the initial level (see Figure 1 and Table 1).

It has been noted in the literature that when the subject is exposed to transverse acceleration, there is a redistribution of blood in the pulmonary circulation, with its deposition in the vessels most distant from the center of rotation (A. A. Kiselev; Blanchard; Hershgold). Under /47 these conditions an important role is played by the cardiovascular reflexes from the pulmonary vessel receptors. It is probable that during transverse acceleration the hemodynamic changes in the pulmonary circulation create conditions under which the resistance in the system of the pulmonary artery increases, the load is increased on the right ventricle, and the left heart gets insufficient blood. A similar state produces the "unloading reflex" -- a primary reaction of the organism directed at unloading the pulmonary circulation and lightening the work of the right ventricle (V. V. Parin). During acceleration, this reflex does not appear in its classical form; however, its vascular component -- decreased arterial pressure at the beginning of exposure -- is preserved. This reaction was clearly pronounced in the animals when the excess gravity was maintained for 30 seconds. However, during acceleration, this reflex is probably a negative factor, exemplifying the fact that a useful adaptive reaction of the organism can, under certain conditions, be transformed into its opposite.

TABLE 1. CHANGES IN THE FUNCTION OF THE CARDIOVASCULAR SYSTEM IN INTACT ANIMALS EXPOSED TO AN ACCELERATION OF 9 G FOR 1 MINUTE.

Parameter	Initial data	Acceleration		After exposure (in minutes)	
		B	E	1	3
Rate of cardiac contraction (beats) per minute	130 123	+30 +24	+54 +33	+8 +12	0 0
Pulse pressure in the aorta (mm Hg)	46 52	−20 −12	−18 −9	+3 +8	−6 0
Average pressure during systole in the aorta (mm Hg)	127 115	−27 +17	+4 +28	+11 +17	+7 +12
Cardiac output (in %)	100 100	−27 −8	−14 5	+13 +27	−13 0
Peripheral resistance	0,0204 0,0179	+0,0012 −0,0065	+0,0040 +0,0034	−0,0008 −0,0017	+0,0044 +0,0019

Remarks: The first line corresponds to the indexes for an increase in acceleration to 9 G in 30 seconds; the second line to an increase in 3-1/2 minutes. The difference in indexes is statistically significant within $P < 0.5$-0.01.

Symbols: + or - indicates a corresponding increase or decrease in the index expressed in absolute units (cardiac output in %) with respect to the initial values. B = beginning, E = end or an acceleration of 9 G.

This is explained by the fact that as acceleration increases, the redistribution of the blood in the lungs is intensified and the unloading of the pulmonary circulation does not occur. When there is an overload in the pulmonary circulation, a definite blood-flow is established and the subsequent changes are characterized by mobilization of the pressor mechanisms which increase vascular tone and arterial pressure. Thus, a new level for the functional state of the cardiovascular system is established which, within physiologically tolerable limits of acceleration, corresponds to the demands of the organism. This compensatory reaction of the cardiovascular system is directly proportional to the time required to reach the 9 G acceleration. In other words, the period of increasing acceleration plays an important role in the mechanism of the compensatory-adaptative reactions of the cardiovascular system during the period of stabilized exposure (overload of 9 G). This view is confirmed by our experiments (see Figure 1 and Table 1). /48

An important role in the formation of the compensatory-adaptive mechanisms of the circulatory apparatus during acceleration is played by the reflexogenic zones of the cardiovascular system.

In the same animals, after bilateral denervation of the sinocarotid zones, more abrupt impairments in hemodynamics were observed (Figure 2, Table 2).

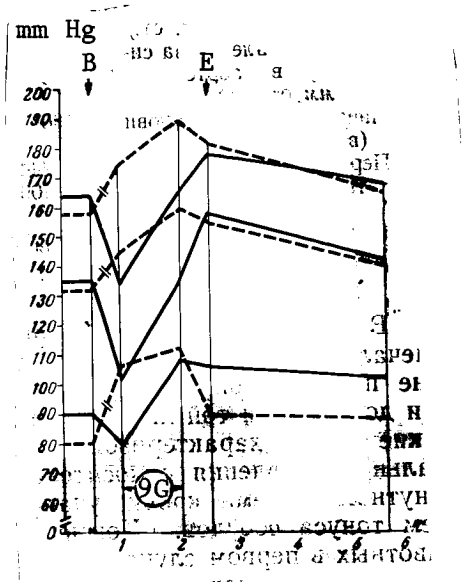

Figure 2. Changes in the Blood Pressure of Animals After Bilateral Denervation of the Sinocarotid Zone. Conditions: Time for Attaining Maximal Acceleration: Solid Line 30 Sec., Dotted Line 3-1/2 Min.

Legend (Top to Bottom): systolic pressure in the left ventricle; systolic pressure in the aorta, diastolic pressure in the aorta; B = beginning, E = end of exposure

TABLE 2. CHANGES IN THE FUNCTION OF THE CARDIOVASCULAR SYSTEM IN ANIMALS AFTER DENERVATION OF THE SINOCAROTID ZONE (ACCELERATION = 9 G; DURATION OF EXPOSURE = 1 MINUTE)

Parameter	Initial data	Acceleration		After exposure (in minutes)	
		B	E	1	3
Rate of cardiac contraction (beats) per minute	160 159	+19 +39	+31 +30	2 +6	0 -6
Pulse pressure in the aorta (mm Hg)	35 43	-11 -5	-12 +6	+12 +25	+1 +15
Average pressure during systole in the aorta (mm Hg)	137 143	-52 2	-31 13	+6 +9	+4 +26
Cardiac output (in %)	100 100	-23 +10	-22 +35	+36 +64	+3 +29
Peripheral resistance	0.0244 0.0209	-0.0047 -0.0015	+0.0004 -0.0041	+0.0056 -0.0065	0.0018 -0.0019

At the beginning of the exposure, when the acceleration was developed in 30 seconds, a more pronounced decrease in arterial pressure was noted against the background of a drop in vascular tone and cardiac output. When the same acceleration was attained in 3-1/2 minutes, the hemodynamic shifts were characterized by slight fluctuations in arterial pressure with respect to the initial level, and by an increase in cardiac output, acceleration of heart rate, and decreased vascular tone. The compensatory reaction in the denervated animals appeared after the centrifuge had stopped in the first case (30 second acceleration buildup) and by the end of the exposure in the second case. However, in both cases it was weakly pronounced. Its manifestations are explained by the function of the aortic reflexogenic zone.

Thus, slowly increasing acceleration is more physiological since gradually increasing changes in the system of the pulmonary artery facilitate the timely function of the control mechanisms which ensure the adaptation of the organism to excess gravity. Even under these conditions, the intactness of the sinocarotid zone has a definite significance in the regulatory mechanisms of the circulation. The choice of the optimal time for acceleration buildup plays an important role in the formation of the compensatory-adaptative reactions and has substantial significance in the over-all complex of conditions determining the organism's resistance to excess gravity.

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REACTION OF SOLITARY NEURONS IN THE VISUAL REGION OF THE CAT'S CEREBRAL CORTEX TO STIMULATION OF THE VESTIBULAR APPARATUS

M. G. Kutateladze

ABSTRACT. Effects of vestibular excitation (exposure to 0.1 to 2 G) on the activity of the neurons of the optic cortex were studied in cats. The microelectric technique was used to monitor the neurons. The results obtained were processed by correlation analysis. Despite the change in the frequency characteristics of the neuron pulse activity, no correlation was found between the changes in neuron activity and the changes in acceleration values. This suggests that excitation of the vestibular apparatus produces a nonspecific effect on the optic cortex.

The specific conditions of space flight (weightlessness, acceleration, excess gravity) have created a number of problems connected with the interaction of those analyzers which bear the responsibility for orientation in space and maintenance of equilibrium. These functions are performed with the participation of many analyzers, among which the leading role is played by the vestibular and visual analyzers. /49

It is well known that stimulation of the vestibular apparatus can affect the functional state of the visual analyzer.

Thus, Ye. M. Belostotskiy and S. A. Il'yina discovered that when there is such stimulation, the sensitivity of the peripheral vision is decreased. O. A. Chernikova observed a narrowing of the field of vision. V. I. Kopanev noted a decrease in the excitability and lability of the visual analyzer and a decrease in visual acuity during rocking motion.

Graybiel and Clark, Graybiel and Hupp, Graybiel, M. D. Yemel'yanov, and A. G. Kuznetsov, and V. V. Baranovskiy et al. have shown that stimulation of both the semicircular canals and the otolithic apparatus is capable of producing varied visual illusions. There have been attempts at electrophysiological studies of the functional state of the visual analyzer during vestibular stimulation. Thus, Grusser and Grusser-Cornhels, and Grusser et al. discovered that when the labyrinth is polarized by direct current, activation of some of the neurons of the visual region occurs. This reaction, it is believed, is specific. At the same time, G. I. Gorgiladze and G. D. Smirnov, as well as Kornhuber and Fonseca, found neurons which were activated when the labyrinth was polarized in other sections of the cerebral cortex as well (auditory, sensory, etc.), and they therefore concluded that the change in neuronal activity in the visual region when the vestibular apparatus is stimulated is not specific. The method of stimulating the vestibular apparatus used by these authors for studying the reaction in the visual region of the /50

cerebral cortex was inadequate. Therefore, the solution to the problem of the specificity of the effect of this stimulation on the above mentioned region of the cortex cannot be considered final.

Considering the importance of clarifying the problem of the functional connections between the visual analyzer and the vestibular apparatus, we considered it particularly advisable to study the change in neural activity in the visual region during adequate stimulation of the vestibular apparatus.

Technique

The experiments were performed on 20 adult cats (weighing 2.5 to 4 kg). An animal under ether anesthesia was installed in a stereotaxic device; then a tracheotomy and curarization (5 mg/kg of *diplacin*), were performed after which the animal was switched over to artificial respiration.

A wide craniotomy ensured access to the hemisphere. After opening the dura mater, the brain was perfused with warm mineral oil. In order to decrease pulsation, the cisterna magna was dried and a pneumothorax was performed. Then the animal was placed in a dark chamber on an experimental stand facilitating stimulation of the otolithic apparatus (vertical displacement with a linear acceleration of 0.1 to 1 G).

The experiment began 1-1/2 hours after ether administration was terminated and the animal had been placed on artificial respiration. The extracellular activity of the separate neurons of the visual region (of the cerebral cortex) was recorded by glass microelectrodes with a tip diameter of 0.5 to 2 microns filled with 3 M KCl. For recording purposes, a UBP 1-01 alternating current amplifier was used with the "Sanei" oscillograph and the MAG-8 tape recorder.

The data obtained were processed by determining the average frequency of spike sequence in 1 second at different periods of the experiment (background, rocking motion). Since this method did not permit an accurate evaluation of the nature of the changes in neuronal activity as affected by rocking motion, we used the method of autocorrelation analysis. This method permits the isolation of the periodic signals against the background of noise and thus enables one to establish the interconnection between the change in the parameter being recorded and the change in acceleration. In our case, the periodic signal was rocking motion (change in acceleration). The calculations were performed on the Dnepr-1 computer wing, the formula:

$$R_x(\tau) = \frac{\sum_i^{n-\tau} \approx 1 (x_i - M_x)(x_i + \tau - M_x)}{D_x (n - \tau)},$$

where Rx (τ) is the standardized correlation function; x_i is the value of the inter-spike interval; M_x is the average value of the inter-spike interval; D_x is the dispersion of distribution of the inter-spike intervals; n is the total number of intervals studied; and τ is the ordinal number of the interval.

Since the correlation function obtained is a function of the number of the inter-spike interval, the time value of the fluctuation period of the correlation function was determined by the formula:

$$T = \frac{1}{n_1} \cdot M_x \cdot n_2,$$

where n_1 is the number of points in a one-second interval (the inter-spike intervals and number of points on the intervals were determined by using the "Orbita" semiautomatic device); and n_2 is the number of points deposited on one interval of the correlation function. /51

Results and Discussion

We recorded the activity of 113 neurons, of which 89 were studied in detail and processed. All neurons were spontaneously active. Their activity was non-rhythmic in nature. The background activity of the neurons in the visual region of the cerebral cortex was extremely variable: it fluctuated between 1 and 44 impulses per second.

After the background activity of the neuron had been recorded, rocking was performed 15 times in 20 seconds (acceleration 1.2 to 1.4 G). It turned out that the neurons studied responded in different ways to the rocking motion. It was possible to identify the following types of changes in neuronal activity: 1) increased activity in 54% (48 neurons); 2) decreased activity in 24.7% (22 neurons); 3) phasic changes in neuronal activity in 4.5% (4 neurons); 4) absence of visible reaction in 10.1% (9 neurons).

After the rocking had ceased, the activity in one portion of the neurons continued to increase, in another it decreased, and in a third the activity was restored.

Processing of the data by the correlation method showed that for these 89 neurons of the visual region of the cerebral cortex, despite the quantitative changes in their pulsatile activity during rocking (slowdown or speedup), the correlation function did not contain periodic components, i.e., the neurons of this region did not reveal any reactions to periodic changes in the magnitude of acceleration. The correlation function of these neurons is given in Figure 1.

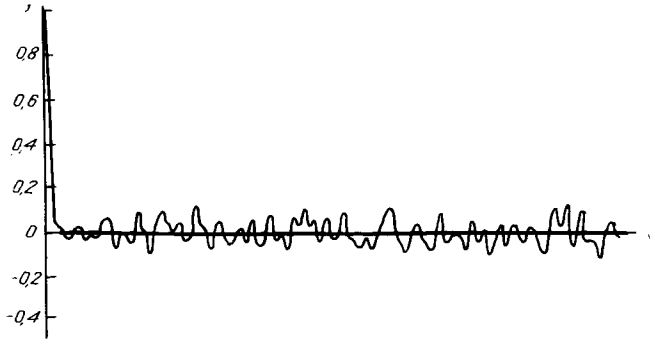

Figure 1. Correlation Function of the Inter-spike Intervals of the Neurons of the Visual Region of the Cerebral Cortex

Besides the visual region, we studied the gyrus ectosylvius anterior, gyrus ectosylvius medialis, and gyrus suprasylvius anterior. It turned out that only the neurons of the gyrus suprasylvius anterior showed a relationship between the response and adequate stimulation of the vestibular apparatus. The correlation function of these neurons did contain a periodic component (Figure 2).

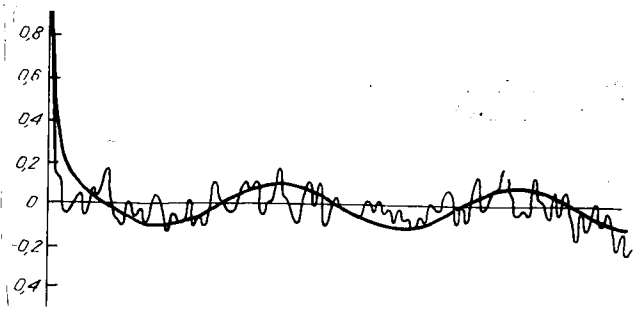

Figure 2. Correlation Function of the Inter-spike Intervals of the Neurons of the Gyrus Suprasylvius Anterior (Vestibular Zone)

Thus, both polarization and adequate stimulation of the vestibular apparatus by rocking produce a change in the pulsatile activity of the neurons in the visual region. Use of the correlation-analysis method make it possible to establish the fact that these changes are nonspecific in nature since the correlation function of the inter-spike intervals of the neurons of this region of the cortex does not contain a periodic component. /52

Thus, the data obtained show that by themselves the changes in the pulsatile activity cannot serve as a basis for the solution of the problem of the specificity of responses.

On the basis of the results of this work, it is possible to conclude that adequate stimulation of the vestibular apparatus by a rocking motion has a nonspecific effect on the functional state of the visual region of the cerebral cortex.

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SYNTHESIS OF TISSUE PROTEINS IN ANIMALS DURING HYPODYNAMIA

I. V. Fedorov, V. N. Vinogradov, Yu. I. Milov, and L. A. Grishanina

ABSTRACT. A 10 to 15 day exposure of rats to hypodynamia caused a significant decrease in the rate of protein synthesis in their liver, kidneys, intestinal walls, heart, and skeletal muscles. The rate had not returned to its initial values by the 6th day after the 15-day exposure to hypodynamia. By this time, normalization of the peripheral blood picture had likewise not commenced, nor had the glycogen level in the liver or weight of the adrenals begun to normalize.

The precence of a substantial disruption in protein metabolism as the result of hypodynamia has been demonstrated in the work of a number of authors (Cuthberton; Deitrick et al.; Heilskov and Schonheyder; Graveline; Graveline et al.) on the basis of an analysis of the blood, urine, and feces of humans. /53

Changes in metabolism in the organs and tissues of animals have not been studied, partially because of the absence of a suitable experimental model of hypodynamia. The model developed by the present authors has made it possible to study the rate of protein synthesis in the tissues of animals during hypodynamia using the method of radioactive labeling.

Technique

The experiments were performed on white male rats weighing 160 to 200 g. Simultaneous studies were made of healthy rats in the control group and of test rats after 2, 10, and 15 days of hypodynamia. The animals of both groups received water and concentrated food ad libitum. Each rat was placed in a separate compartment of a special metabolism cell made of organic glass.

Radioactive amino acids were injected intraperitoneally 1, 2, and 4 hours before the animals were sacrificed in amounts calculated as equalling 10,000 counts per minute per gram of body weight. We used glycine, alanine, phenylalanine, and methionine, labeled with C^{14} in the first position, and methionine-S-35. After sacrifice (decapitation), the liver, kidneys, heart, spleen, part of the small intestine, and the skeletal muscles (from the region of the right rear femur) were taken from the rats for investigation. The tissues were treated in sequence with trichloroacetic acid, alcohol, an alcohol-ether mixture, and with pure ether by the usual method (I. I. Ivanov et al.).

The radioactivity was determined on the PST-100 counter with a T-25-BFL end-window counter in 10 mg of protein.

Experimental Data and Discussion

The rate of synthesis and decay of the total tissue proteins was evaluated from the change in the rate of incorporation of the radioactive label. A decrease in label incorporation noted shortly after its injection, as well as a shift in the incorporation maximum to later times, was usually interpreted as proof of a decrease in protein synthesis in the tissue studied.

In Tables 1, 2, and 3, the average results of experiments are given for each group of animals, expressed in counts per 10 mg of protein per minute. Two hours before sacrifice the animals were given an intraperitoneal injection of a radioactive amino acid solution emitting 10,000 counts per minute per gram of body weight. In those cases when it was not possible to introduce an exact amount of the preparation, the results were adjusted accordingly. The numerical data obtained in the experiments are statistically significant and differ from the control of $P \leq 0.05$.

In all variants of the experiment, after 3 days of hypodynamia, a statistically significant decrease in label incorporation into the proteins of the skeletal muscles was noted. Incorporation of label into the liver proteins, however, remained on the same level as in the control animals, or even increased somewhat. These changes are typical of the action of adrenocortical hormones and are usually observed during stress reactions. In the pathomorphological studies by one of the authors, an increase in the weight of the adrenals and hypertrophy of the adrenal cortex were demonstrated. However, the blood picture (lymphocytosis and eosinocytosis) and glycogen impoverishment of the liver were not typical for such states. /54

After 10 or even 15 days of hypodynamia, the rate of label incorporation into the proteins of all the organs except the skeletal muscles continued to decrease, and in a number of cases this decrease was statistically significant. When a mixture of 4 amino acids was used for some tissues, the decrease was not statistically significant, but still different from the control by 15 to 20%. Studies made 1, 2, and 4 hours after amino acid injection showed that the maximum incorporation for the proteins of some tissues was delayed to later periods.

The decrease in label incorporation into the proteins of all the tissues studied was usually typical of the state produced by decreased production of somatotropic hormone by the hypophysis (S. G. Gasanov).

For 6 days after the 15 days of hypodynamia, the rate of incorporation of label into the tissue proteins was not restored. /55

Thus, in most of the organs and tissues studied, there was a decrease in protein synthesis during hypodynamia. Indirect evidence of the decrease in the synthetic processes in the muscle tissue is also given by the development of creatinuria.

In the over-all equilibrium of the organism, the decrease in protein synthesis causes a predominance of catabolic processes over anabolic ones. A negative nitrogen balance develops, the animals often lose weight, and the

TABLE 1. RATE OF METHIONINE-1-C-14 INCORPORATION INTO THE TISSUE PROTEINS OF HEALTHY AND HYPODYNAMIZED RATS OF THE FIRST SERIES OF TESTS (NOV.-DEC. 1965) (IN NUMBER OF COUNTS PER 10 MG OF PROTEIN PER MINUTE).

Period of study	Statistical index	Small intestine	Skeletal muscles	Liver	Kidneys	Spleen	Heart
Control	n	12	12	12	12	12	12
	$M \pm m$	858±35	84±5	486±21	877±38	414±22	176±19
3 days of hypodynamia	n	10	10	9	9	10	10
	$M \pm m$	728±34	44±6	491±30	951±48	363±16	165±11
	P	<0.05	<0.001	>0.5	>0.20	<0.1	>0.5
10 days of hypodynamia	n	6	6	5	6	6	6
	$M \pm m$	644±62	63±13	370±36	669±38	328±33	134±9
	P	<0.05	>0.10	<0.05	<0.01	>0.1	<0.1
15 days of hypodynamia	n	8	8	7	8	8	8
	$M \pm m$	550±33	67±6	291±36	577±27	267±9	115±10
	P	<0.001	<0.1	<0.01	<0.001	<0.001	<0.05
6 days of recovery after 15 days of hypodynamia	n	5	5	5	5	5	5
	$M \pm m$	557±38	99±13	263±19	570±39	337±27	119±6
	P	<0.01	>0.10	<0.01	>0.01	<0.1	<0.05

n = number of animals

TABLE 2. RATE OF METHIONINE-S-35 INCORPORATION INTO THE TISSUE PROTEINS OF HEALTHY AND HYPODYNAMIZED RATS OF THE SECOND SERIES OF TESTS (JAN.-MAR. 1966) (IN NUMBER OF COUNTS PER 10 MG OF PROTEIN PER MINUTE).

Period of study	Statistical index	Small intestine	Skeletal muscles	Liver	Kidneys	Spleen	Heart
Control	n	19	18	19	19	19	19
	$M \pm m$	627±25	57±4	403±17	959±50	314±20	129±8
3 days of hypodynamia	n	10	10	10	10	10	10
	$M \pm m$	510±36	24±4	401±29	766±57	206±14	93±11
	P	<0.05	<0.001	>0.1	<0.05	>0.1	>0.1
10 days of hypodynamia	n	9	9	9	7	9	9
	$M \pm m$	527±42	34±6	379±29	770±74	228±16	95±7
	P	>0.1	<0.02	>0.5	>0.1	<0.01	<0.01
15 days of hypodynamia	n	7	7	7	7	7	7
	$M \pm m$	494±45	51±6	352±37	651±33	287±27	102±9
	P	<0.05	>0.5	>0.5	<0.01	>0.5	>0.1
6 days of recovery after 15 days of hypodynamia	n	7	7	7	7	7	7
	$M \pm m$	445±30	71±10	238±17	524±34	269±22	90±6
	P	<0.01	>0.5	<0.001	<0.001	> 0.2	<0.01

n = number of animals

TABLE 3. RATE OF INCORPORATION OF A MIXTURE OF 4 AMINO ACIDS, CONTAINING C^{14} INTO THE PROTEINS OF THE ORGANS AND TISSUES OF HEALTHY AND HYPODYNAMIZED ANIMALS (8) OF THE THIRD SERIES OF TEST (MARCH-MAY 1966) (IN NUMBER OF COUNTS PER 10 MG OF PROTEIN PER MINUTE).

Time of sacrifice after injection of amino acids (in hours)	Period of study	Statistical index	Small intestine	Skeletal muscles	Liver	Kidneys	Spleen	Heart
1	Control	$M \pm m$	523±51	41±4	393±54	550±49	330±34	106±8
	3 days	$M \pm m$	479±53	29±5	400±50	569±70	233±23	103±13
		P	>0.10	<0.10	<0.10	<0.10	<0.05	>0.10
	15 days	$M \pm m$	442±28	38±3	309±29	516±33	226±14	95±7
		P	>0.10	>0.10	>0.10	>0.10	>0.10	>0.10
2	Control	$M \pm m$	615±58	59±5	375±40	638±32	318±25	131±10
	3 days	$M \pm m$	502±52	33±4	375±34	665±51	254±20	114±10
		P	>0.10	<0.02	—	>0.10	<0.10	>0.10
	15 days	$M \pm m$	461±57	55±8	320±21	561±42	235±17	118±10
		P	<0.10—0.05	>0.10	>0.10	>0.10	<0.05—0.02	>0.10
4	Control	$M \pm m$	529±38	65±4	329±13	602±37	308±18	145±9
	3 days	$M \pm m$	491±32	39±2	357±21	578±52	251±29	124±8
		P	<0.10—0.05	<0.001	>0.10	>0.10	>0.10	>0.10
	15 days	$M \pm m$	461±28	52±6	318±16	505±25	229±25	125±11
		P	> 0.10	>0.10	>0.10	<0.10—0.05	<0.05—0.02	>0.10

Note: The mixture of 4 amino acids (each responsible for 25% of the activity) was administered 1, 2, or 4 hours before the animals were sacrified.

symptoms of general exhaustion are noted. Naturally, the impairment in protein synthesis in the tissues, in conjunction with all the other changes, produces a greater sensitivity of such animals to excess gravity and other flight factors.

One of the most pressing tasks of studies in this field is the search for and testing of methods for facilitating the normalization of protein synthesis in the tissues.

Conclusions

1. The rate of labeled amino acid incorporation into the proteins of the liver, kidney, spleen, small intestinal wall, heart, and skeletal muscle tissues was decreased in all cases under hypodynamia independently of the time of year when the tests were performed, the use of several amino acids, and variations in the time of sacrifice after their injection. When the time of hypodynamia was lengthened (3, 10, and 15 days), the degree of decrease incorporation of label into the tissue proteins was, as a rule, also increased.

2. Six days after 15 days of hypodynamia, there was only an inclination /57
toward a normalization of the rate of label incorporation into the proteins of all the tissues studied. By this time, normalization of the peripheral blood picture had likewise not commenced, nor had the glycogen level in the liver or weight of the adrenals begun to normalize.

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SPACE MEDICINE

PROBLEMS OF ACCELERATION IN SPACE PHYSIOLOGY

A. S. Barer

ABSTRACT. On the basis of data in the literature and his own findings, the author discusses biomedical problems related to the evaluation of human tolerance to accelerations and the development of methods to increase it. An evaluation is made of the primary factors which limit human tolerance to acceleration. In this connection, the significance of oxygen metabolism in vital organs is emphasized. It is shown that tolerance to impact acceleration depends on the strength of different organs and tissues rather than on the pattern of their physiological responses.

Man encounters various types of acceleration at practically every stage /57
of a space mission. We will dwell primarily on the prolonged accelerations which arise during launching of a spacecraft and its reentry into the dense layers of the atmosphere. Launching of a spaceship is accompanied by accelerations arising due to the work of the engines of the carrier socket. The character of these accelerations depends on the type of rocket, the work of its individual stages, and the velocity which the ship must acquire.

Prolonged accelerations can reach maximum magnitudes when the spacecraft reenters the dense layers of the earth's atmosphere or of other planets. The magnitudes of these accelerations depend on a number of factors, including, primarily, flight velocity, angle of reentry, the aerodynamic characteristics of the ship, etc.

In the very first space flights (unlike flights in conventional aircraft), it was possible to use one of the most effective methods of protection against the harmful effects of acceleration, namely, optimal positioning of the man relative to the acceleration vector (Clarke et al.; A. R. Kotovskaya et al., 1962; A. S. Barer et al., 1964).

The advantage which is achieved by changing body position relative to the acceleration vector is easily estimated from the curves in Figure 1, which indicates the limits of human tolerance to prolonged accelerations in different directions (based on the data of our laboratory). The essence of this effect is well known. The fact is that the more the acceleration vector deviates from the direction of the main blood vessels, i.e., from the longitudinal axis of the human body, the smaller the shifts that arise both in general hemodynamics and, accordingly, in the blood supply to the brain. It is

necessary to bear in mind only that a transverse (at an angle of 90°) position of the pilot relative to the direction of acceleration also leads to the occurrence of a number of undesirable symptoms, which will be treated more thoroughly. /58

The difference in the hemodynamic reaction to accelerations acting at different angles (65 and 80°) can be illustrated in Figure 2, which shows the character of the changes in arterial pressure in the brachial artery, i.e., at the level of the heart, at forces from 1 to 10 G.

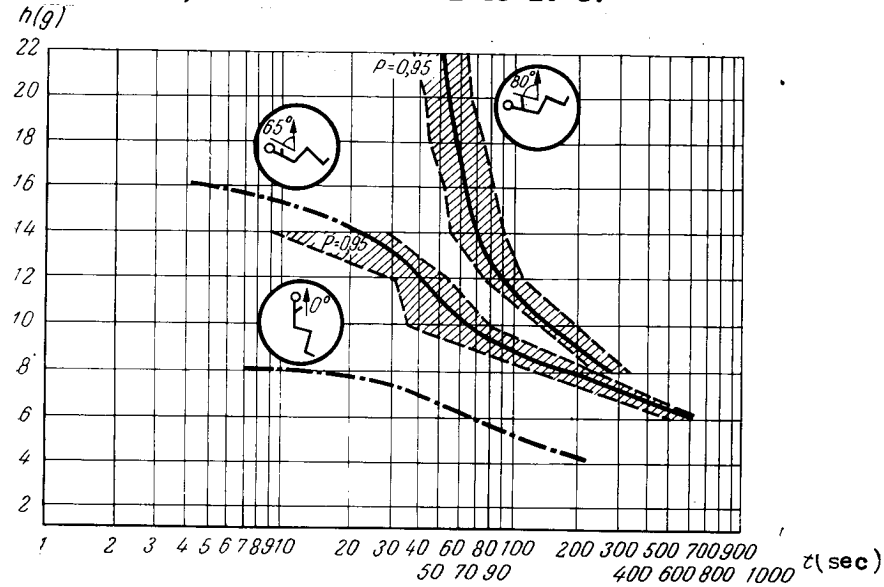

Figure 1. Human Tolerance to Accelerations in Various Directions.

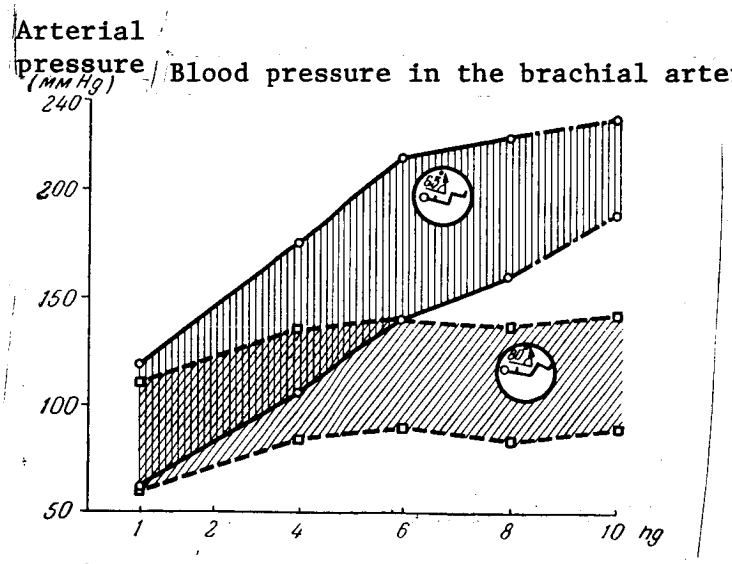

Figure 2. Pressure in Brachial Artery at Various Magnitudes of Acceleration in Experiments With Angles of 65 and 80°.

Nevertheless, what determines human tolerance to acceleration, even with an optimal position of the body relative to the vector? We will dwell primarily on one of the leading limiting circumstances, namely, disturbance of the oxygen balance of the organism.

Hypoxia during acceleration is quite complex and unique (A. S. Barer et al., 1963; Nolan et al.; Ye. A. Kovalenko et al.). It stems not only from disturbances in the systems supplying oxygen but also from the appreciable increase in its requirement owing to the marked elevation of the functional activity of many systems and organs. The specificity of action of acceleration on an organism leads to an inadequate oxygen supply, primarily as a result of disorders in the general and regional circulation and in the system of external respiration. As was already mentioned, shifts in the general hemodynamic picture are more evident the greater the magnitudes reached by the acceleration component which coincides with the direction of the main blood vessels. Shifts in the external respiration system are mainly caused by the transversely directed component of the inertial forces. They are manifested both by difficulties arising in the biomechanics of the respiratory act and by changes on the part of the pulmonary circulation (Herschgold; A. A. Kiselev; Nolan et al.; K. I. Murakhovskiy).

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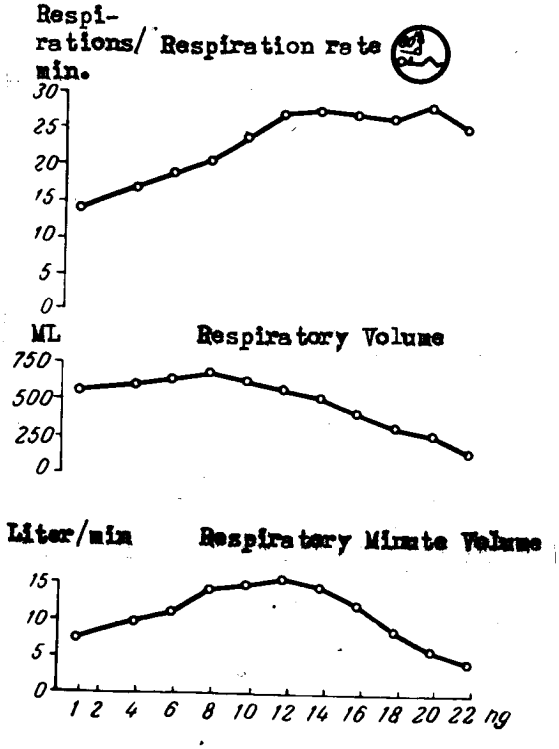

Figure 3. Basic Indices of Human External Respiration at Various Magnitudes of Acceleration.

Figure 3 illustrates the character of the change in the basic indices of external respiration with an optimal body positioning relative to the acceleration vector. The potential possibilities of the respiratory musculature in accomplishing excursions of the thorax and diaphragm can be judged indirectly from the change in vital capacity of the lungs. It has been established that with an increase in acceleration the vital capacity of the lungs steadily diminishes with a gradiant close to 200 ml per G.

The increase in pulmonary ventilation noted before accelerations of the order of 8-12 G is accompanied both by an elevated consumption of oxygen by the organism and by an increase in the production of carbon dioxide. It is interesting that the relative effectiveness of pulmonary ventilation, i.e., the quantity of oxygen utilized from a unit volume of inspired air, steadily decreases with an increase in acceleration (Figure 4). This is related primarily to inhibition of gas exchange at the alveolar-capillary level due to disorders in pulmonary circulation. This circumstance, as well as the appreciable consumption of oxygen by

the respiratory muscles themselves, results in the external respiratory system becoming wholly, so to speak, unprofitable at accelerations above 12-14 G. In this case, a deliberate reduction of pulmonary ventilation, and at 18-20 G a suppression of respiration, can be considered advisable. It has also been established that if the acceleration time from the point of view of tolerance reaches a limiting value, then regardless of the absolute magnitude of acceleration the oxyhemoglobin level in the blood drops to 60-65% and the accumulated oxygen debt amounts to 3-5 liters (C. A. Golov).

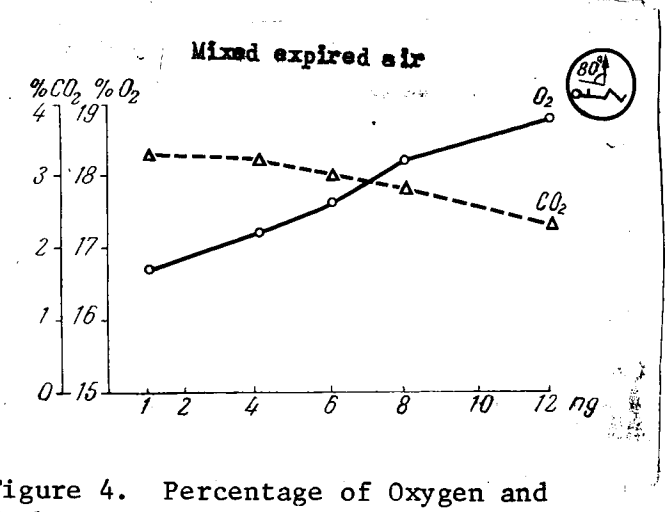

Figure 4. Percentage of Oxygen and Carbon Dioxide in Expired Air at Various Magnitudes of Acceleration.

The fact that the general oxygen debt at these critical accelerations is relatively low confirms the point of view that human tolerance to acceleration is limited not so much by the general oxygen deficit as by disruption of oxygen metabolism in vitally important organs and primarily in the brain, which is extremely sensitive to an oxygen deficiency. /60

Our differential evaluation of the state of cerebral circulation and circulation in the outside vessels of the head showed the presence of a purposeful, selective, compensatory reaction directed toward the maintenance of the cerebral circulation. It was established that up to magnitudes of the longitudinal component equal to 1.6-1.8 G the pulse pressure of the cerebral vessels is elevated regardless of the direction of the total acceleration vector; at 3 G it becomes equal to the initial level, and at 5 G it is 1/2 of this level. With regard to the outside vessels of the head, pulse fluctuations are often not detected at 0.8-1-7 G in the longitudinal component.

It was found in experiments on animals (Ye. I. Sorokina) that under the influence of a 10 G acceleration there is a gradual decrease in oxygen tension in the tissues and a shift of the oxidation equilibrium (redox potential) toward under oxidation simultaneously with a general rise in oxygen consumption. The dynamics of the development of this reaction in various tissues is different. Thus, in the brain these changes, just as recovery of the initial state, occur at a relatively high rate.

The significance of the oxygen supply of an organism for acceleration tolerance was also confirmed by us in experiments where different degrees of rarefaction were created in the pressurized cabins of a centrifuge and in experiments where the test subject breathed air or oxygen under atmospheric or excess pressure (Figure 5).

Does only a disruption of oxygen metabolism limit human tolerance to prolonged accelerations? No, this is not the only factor. In many cases, for

example in experiments on a centrifuge, it has been necessary to stop owing to the occurrence of various painful symptoms. This occurred most often even before the appearance of pronounced signs of hypoxia. With transverse dorso-ventral acceleration, Painful sensations can occur in the epigastric and retrosternal areas, and also along the edge of the costal arch. We have observed cases where these instantaneously ensuing painful sensations led to a reflex arrest of respiration at 10-12 G when the acceleration vector was rigorously transverse (at an angle of 90°) relative to the human body. The nature of such painful sensations has not been fully explained. They are most probably due to deformation of the viscera and stretching of their ligaments and, possibly, of the vascular bundle of the heart. Nor can we reject the idea that myocardial ischemia is the cause of these pains. /61

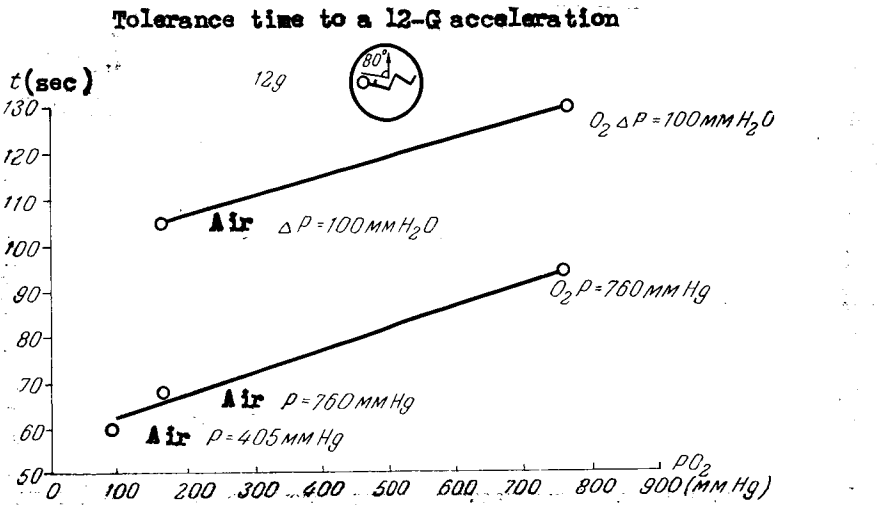

Figure 5. Human Tolerance to a 12-G Acceleration at Various Oxygen Supplies and Respiration Under Excess Pressure

Painful sensations can also be related to defects in the support surface of the astronaut's couch. In this connection we, just as those abroad, resort to individual form-fitting couches. This measure is also expedient because it minimizes such an unfavorable phenomenon as petechiae.

Painful sensations in the limbs can also be associated with disturbances in the regional circulation. This phenomenon occurs in dorso-ventral acceleration. Inertial forces acting in the opposite direction cause an appreciable increase in the blood supply to the vessels of the arms and legs. This becomes more pronounced the greater the distance between the limbs and the trunk, i.e., the greater the pressure drop created between the vascular systems of the trunk and limbs. Petechiae can most commonly be found where there are painful sensations.

There have been experimental cases where it was necessary to stop the effect of acceleration on the human subject because he developed certain

unfavorable symptoms on the part of the heart. This refers primarily to extrasystoles. As a rule, the appearance of extrasystoles is not noticed by the subject. The causes for their occurrence can be quite diverse: from deformation of the heart itself to emotionally caused disturbances in the fine regulatory system of cardiac activity. We, for example, observed a case where extrasystoles rigorously followed the delivery of any verbal commands to the test subject from the control panel.

Visual disorders are rather frequently used in aviation medicine as a criterion for estimating human tolerance to prolonged accelerations. This is because disturbances in visual function in the form of narrowing of the field of vision and the occurrence of a "grayout" and then a "blackout" during longitudinal acceleration are precursors of loss of consciousness as a consequence of diminution of the cerebral blood flow. However, as experiments have shown, in transverse acceleration the use of visual disorders (in the strict sense) is not admissible. The fact is that during longitudinal accelerations a disturbance in visual function can be correlated strictly with disturbances in general hemodynamics. The situation is different in the case of transverse accelerations. Although, in this case, visual disorders also indicate a disruption of the blood supply to the retina, they are caused primarily by disturbance of regional circulation in the ocular vessels due to the acceleration component acting in the "occiput-forehead" direction and actually are not precursors of cerebral circulatory disturbances. For example, with an optimal position of the body at an angle of 80° relative to the acting forces, vision is completely cut off at 14-15 G (Figure 6); however, in this case the person tolerates, without loss of consciousness, almost twice the acceleration and can, therefore, perform specific operations if information on the change of a prescribed parameter is sent not over the visual but, for example, over the auditory channel. /62

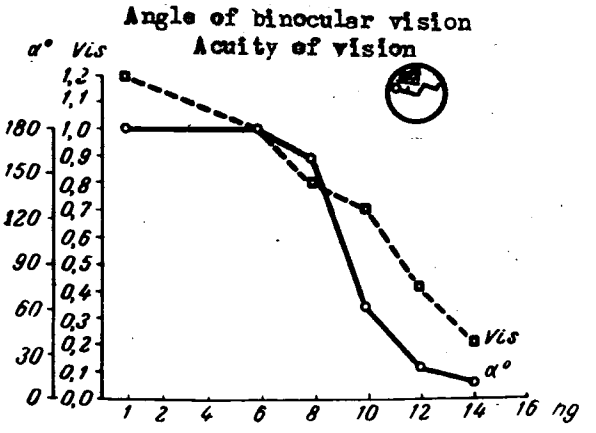

Figure 6. Acuity and Angle of Binocular Vision at Various Magnitudes of Acceleration.

It is natural that, in conformity with the stated problem, the criterion of tolerance can be the capacity of the astronaut to perform various operations. This problem per se is rather complex and many-sided, and it is solved by the entire arsenal of such branches of science as engineering psychology and space physiology. In any case, we can now establish that with the proper selection and construction of indicator systems and manual control units, the astronaut can perform specific operations over practically the entire range of accelerations tolerable with respect to remaining conscious.

The problem of producing artificial gravity in those parts of the flight where weightlessness occurs can be considered an independent section in the science of acceleration.

The presently accumulated experience of orbital flights gives us the right to assert that man can tolerate both weightlessness and the acceleration of the final flight stage for several weeks (and possibly months). The problem boils down to whether the human organism will remain indifferent to longer periods of weightlessness. Theoretical premises give a negative answer to this. Actually, it is difficult to imagine that a biological object that has spent many centuries evolving under conditions of the earth's gravitation will remain indifferent to its absence. Many complex functional systems, to say nothing of the support and motor apparatus, are adapted to work under conditions of gravity. Suffice it to mention the basic principles of function of the cardiovascular system.

The creation of artificial gravity is not only a physiological problem but also a complex engineering problem. For example, it is necessary to solve the problem of the magnitude of acceleration imitating gravity and the ponderable magnitudes of angular and Coriolis accelerations which arise when a spaceship rotates, etc. /63

Let us now consider another type of acceleration which man can encounter during a space flight, namely, the so-called impact accelerations. By this term in space and aviation practice we mean an acceleration which is characterized by large build-up velocities (from several hundred to several thousands of G/sec) and brief effect (fractions of a second).

When can "impact acceleration" actually occur? First, even before lift-off of the rocket as a consequence of troubles in the rocket itself or in other starting systems. This possibility is taken care of on the American "Gemini" spacecraft for example, by "firing" the astronaut and cabin to a safe distance away from the launching pad. The acceleration which occurs in this case is quite similar to that which accompanies the already commonplace catapulting of a pilot from an aircraft.

As a rule, this system ensures the possibility of saving the crew members during the entire flight time with an operating carrier rocket.

The astronaut can also encounter "impact accelerations" at the final flight state, i.e., when returning to earth or when landing on another planet. For example, parachutes are used on modern spacecraft after passing through the dense layers of the atmosphere to reduce landing speed. The abrupt filling of the parachute canopy inevitably gives rise to an aerodynamic impact.

Impact can be created by the spaceship contacting the surface of a planet on which it lands. The problem here reduces to softening the impact by means of engineering and physiological-hygienic measures and improving the conditions of man's tolerance to it.

In view of the shortness of all these effects, man's tolerance to them is limited mainly not so much by the sum of the physiological responses as by the characteristics of the strength of various parts of the body, individual organs, and systems. As is known from the practice of catapulting,

if acceleration acts along the vertebral axis individual vertebrae can be damaged beginning at certain magnitudes of acceleration (20 G and more). Man can tolerate twice the acceleration if it is directed along the "ventro-dorsal" or "dorso-ventral" axis (R. A. Stasevich and P. K. Isakov, 1956). With this direction of acceleration, however, there is a danger of damaging the internal organs and, primarily, the parenchymatous organs.

A substantial role in increasing the resistance of astronauts to "impact accelerations" is played by the complex of engineering measures and, mainly, by systems for softening the impact and assuring proper posture. In recent years form-fitting couches have become very widely accepted. Such a couch, on the one hand, promotes a uniform distribution of pressure on the body and, on the other hand, together with the fastening system, acts, so to speak, as an exterior skeleton unloading the bone-support apparatus of the astronaut during impact (A. S. Barer et al.; G. P. Mirolyubov).

In this short article we have dwelled on the most commonly studied manifestations of the response of an organism to accelerations. The efforts of many scientists working in this area are presently directed toward studying the intimate aspects of the vital activity of an organism under such effects. Particular attention is being devoted to the humoral-endocrine links of regulation and morphological changes in various organs and tissues (I. M. Khazen et al.). /64

There is no doubt that only the combined efforts of physiologists, clinicians, biochemists, biophysicists, and morphologists together with the efforts of physicists, mathematicians, and engineers will permit the achievement of appreciable progress in this complex and, at the same time, quite urgent area of modern astronautics.

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RADIATION SAFETY OF MANNED SPACE FLIGHTS (RADIOBIOLOGICAL ASPECTS)

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N67-29217

ABSTRACT. Safety criteria with regard to crew irradiation on short and long-term space flights are considered. It is important to evaluate the recovery process after repeated exposure to radiation, to determine the degree of radiation damage during flight, and to develop methods of preliminary estimation of the astronaut's radiosensitivity. When evaluating radiation hazards of prolonged space flights, it is of great significance to estimate the radiosensitivity of biological life-support systems. The data on the effects of 126 to 660 MeV protons on some higher plants are presented.

One of the important problems of space biology and medicine is to ensure radiation safety during space flights. The importance of this problem increases appreciably as the duration and range of the flights increase. /64

The effect of cosmic radiations on man is characterized by a number of specific features associated with both the physical properties of the radiation itself and the specific flight conditions.

Galactic radiation is composed of charged particles of high and superhigh energies (protons, α-particles, heavy ions, etc.). Near the earth the charged particles form zones of high intensity, the radiation belts. During periods of high solar activity powerful chromospheric flares occur on the sun, some of which are accompanied by intense streams of high-energy charged particles. Furthermore, when cosmic radiations pass through the skin of the spacecraft and the bodies of the astronauts, secondary particles are formed: neutrons, protons, mesons, γ-quanta, etc. /65

Table 1 presents a brief summary of the data on radiation in space. It shows the tissue doses of cosmic radiations, assuming protection by an aluminum shield (1 g/cm^2 thick).

As can be seen from Table 1, the values of cosmic radiation dosages are often large. However, in a radiobiological evaluation of radiation hazards it is necessary to take into account that as a result of the interaction of cosmic radiations with the protective substance and biological tissue, the spatial distribution of absorbed doses can be uneven.

The degree of uneveness depends on the penetrating capacity of the radiation. The mean free path of protons in biological tissue is 0.124 for an energy of 10 MeV, 2.25 cm, for 50 MeV, and 25.8 cm for 200 MeV. For an

appreciable portion of the spectra of protons of the radiation belts and solar flares, the mean free paths are comparable with the size of the human body.

TABLE 1. RADIATION IN SPACE

Source of radiation	Region of space	Day (rem/day	Comment
Galactic radiation	At heights up to 600 km from the earth's surface	Up to 0.007	Average tissue dose
	Interplanetary space	0.13 0.26	Maximum solar activity Minimum solar activity
	Lunar space	0.13	Maximum solar activity
Radiation belts	At heights up to 600 km from the earth's surface	0.12 2.0	Surface dose of protons Surface dose of electrons
	At heights up to 1,500 km	Up to 5 Up to 3,000	Average dose of protons Surface dose of electrons
	At heights of 1500-1800 km	Up to 100 Up to 50,000	Average dose of protons Surface dose of electrons
Solar flares 23/II 1956 23/ V 1959 3/IX 1960 12/XI 1960	Outside the earth's magnetosphere	 280 5,400 2.5 1,000	 Surface dose during flare

Furthermore, with an increase in the energy of the charged particles, /66
the contribution of the secondary particles formed as a result of the interaction of nuclei with tissue substantially increases along with an increase in their penetrating capacity. This contribution depends on the total mass of the irradiated object and to some degree on its geometry.

With a thin protective shield and soft radiation spectrum the gradients of absorbed doses in the body can be appreciable, in certain cases, reaching several orders of magnitude.

The presence of such a complex picture of the interaction of cosmic radiation with human tissue necessitates the evaluation of radiation hazards in terms of specific criteria. For example, for the low-energy radiations of space (electrons of the Van Allen radiation belts), we can use the surface dose and the effect of radiation on such critical organs as the skin and crystalline lens as a criterion for estimating radiation hazard. For the hard region of the spectra of protons of the radiation belts and of solar flares, the average tissue dose can serve as the criterion. In this case the gradients of the absorbed doses in the body are comparatively small, and the radiobiological effect will be due to uniform irradiation of all organs and tissues of the organism. Thus, in all cases, a determination of the degree of nonuniformity of the dose distribution in the body should precede a selection of the criterion for evaluating the radiation hazard.

The quantitative expression of the criterion of radiation hazard also depends on the conditions of the space flight and mainly on its duration. At present, with space flights lasting up to one month, a value of 15 rem per flight is recommended as the maximum permissible dose for astronauts. The total protection of the inhabited compartments of the spacecraft should reduce the total dose from galactic radiation, radiations of the Van Allen belts, and from other possible sources to a magnitude not exceeding 15 rem.

For ionizing radiation, the occurrence of which is probabilistic (for example, for the ionizing radiation of solar flares), it is expedient to establish the justified risk dosage (JRD). On orbital and lunar flights the JRD can be calculated at 50 rem and can be used as the criterion when designing the shielding of a special radiation shelter on the spacecraft for the crew to reside in during powerful solar flares. In this case, the shielding of the shelter should be such that it not only limits the magnitude of the dosage to 50 rem during the flight but also reduces the risk of exceeding the value. The concept of "shielding reliability" is used as the characteristic of such shielding, defined as the probability that the justified risk dosage will not be exceeded under given flight conditions (trajectory and duration of flight, spacecraft design, shielding of the shelter, etc.).

In orbital flights during which the spacecraft can be landed within a short time, the critical dose (CD), which should not be exceeded and which requires an immediate decision on whether to stop the flight, must be determined. A dosage of 125 rem is recommended as this criterion.

Taking into account the radiation conditions on a flight to Mars, it is reasonable to establish only the justified risk dosage for the crew, since, during the flight (2-3 years), the total dosage can reach 250-350 rem due to galactic radiation and solar flares alone.

The problem of substantiating standard levels of radiation for long space flights is actually a problem of estimating the total dosage with consideration

of the recovery of dysfunctions and the development of remote after-effects. Unfortunately, despite the numerous studies into problems of post-irradiation recovery, this problem remains unsolved, particularly as related to the specific conditions of radiation during space flights. /67

Even accurate dosimeter information from on board the spacecraft relative to the magnitude of the absorbed dose is inadequate for taking appropriate therapeutic and preventive measures, since the range of the individual radiosensitivity of man is too great. Hence, it is necessary to work out criteria and methods for evaluating the degree of severity of radiation damage to an organism directly on board the spacecraft.

The selected criteria for estimating the degree of radiation damage should be distinguished by specificity and high reliability and should characterize the clinical state of the astronaut most completely. In the radiobiological plan it is necessary to provide for an analysis and comparison of all medical information obtained from the spacecraft.

At definite time intervals, the ground-based radiation safety service should obtain data characterizing the condition of the most radiosensitive systems of the organism and the severity of radiation damage. This group of data should include information on the quantitative composition of the peripheral blood, presence of dyspeptic disorders, development of the hemorrhagic syndrome in the spacecraft crew members, etc. A number of special tests, particularly biochemical, can be quite valuable. As a method for the quantitative assay of radiation damage we can, for example, determine substances containing deoxyribose (so-called Dische-positive substances) in the urine. The appearance of these substances in the urine, in the opinion of many authors, is specific for the effect of ionizing radiation and is noted in irradiated mice, rabbits, dogs, monkeys, and man.

The group of quite radiosensitive tests for evaluating the immunological state of the organism (the bactericidal capacity of the skin, its microflora, phagocytic activity of the neutrophils) deserves the greatest attention.

Investigations to substantiate the criteria and selection of methods for estimating the severity of radiation damage in astronauts on board a spaceship are of great practical value and are related in many respects to the further development of studies in quantitative radiobiology.

The problem of evaluating individual radiosensitivity and the appropriate selection of astronauts is still not solved. At present there are practically no methods for a preliminary evaluation of human sensitivity. In this connection we can only express certain hypothetical opinions on this matter.

It was previously established that the bioelectrical activity of the human brain can be changed following irradiation in small doses (Yu. G. Grigor'yev, 1954). I. G. Darenskaya and A. B. Tsypin showed that animals in which this reaction was initially noted proved to be less radiosensitive. Consequently, it can be assumed that the effective use of these data, for example in roentgenoscopy, will prove to be useful for the preliminary evaluation of the radiosensitivity of an astronaut.

Furthermore, the question of the possibility of conducting such an evaluation by irradiating an autogenous cell culture of the astronaut taken long before the flight, should be examined.

Presently, a new problem arises when solving the problem of radiation safety during long space flights. We have in mind the radiation protection of /68
the life-support system of the spacecraft crew. Cosmic radiation, especially of protons of solar flares, is extremely dangerous to the vegetation link in the life-support system. Calculations show that with a shielding thickness of 1 g/cm^2 the dose from several powerful solar flares can amount to several thousands of rad. Experimental evidence, obtained with the participation of D. F. Gertsuskiy, V. M. Abramova, L. V. Alekseyenko, L. V. Nevzgodina, and others, shows that doses of proton irradiation which are often commensurate with the level of radiation of solar flares can lead to substantial radiation damage to plants (Table 2).

TABLE 2. DAMAGING ACTION OF 126-600 MeV PROTONS ON VARIOUS PLANT SPECIES

Object	Lethal dose of 126-660 MeV protons (in rad)
Cabbage	90,000
Radishes	90,000
Potato (tubers)	5,000
Tomatoes	25,000
Lettuce	25,000
Potato (seeds)	40,000
Phaseolus	10,000

The data given in Table 2 pertain only to the effect of radiation on seed material (seeds or tubers). Vegetation plants are appreciably more sensitive to radiation.

The effect of stimulation induced by small doses of radiation, which can disrupt the equilibrium in the closed ecological system on board a spacecraft, can prove to be significant from the point of radiation hazard to the vegetation.

Our experiments on the spacecraft "Kosmos-110" showed that many space flight factors have a pronounced stimulating effect on plants.

The results of investigating the RBE of protons for certain plants proved to be quite unexposed. The coefficients of the RBE of 126 and 660 MeV protons for cabbage, radishes, lettuce, potatoes, and other plants, which were determined on the basis of different evaluation criteria (cytogenetic and agrobiological), varied from 1.5 to 5.5 and higher and depended directly on dose (L. V. Nevzgodina et al.). Thus, the RBE of protons for potatoes changed 1 to 3.7 depending on dose (500-50,000 rad). The over-all radioresistance of plants also affects the RBE. The maximum value of RBE of 660 MeV protons was 2.6 for lettuce (a radiosensitive plant) and 5.5 for carrots (a resistant plant).

Thus, the RBE of high-energy protons (660 MeV) for plants can differ from unity to a greater degree than for animals (A. F. Bibikova et al.).

We have touched only upon a few problems pertaining to the radiation safety of space flight. Their examination shows that this problem is complex and its solution requires the combined efforts of radiobiologists, physicists, and engineers and the setup of broad radiobiological experiments both on the ground and in flights.

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APPLICATION OF ONBOARD COMPUTERS FOR MEDICAL MONITORING AND INVESTIGATIONS DURING MANNED SPACE FLIGHTS

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N67-29218

ABSTRACT. The principles of developing diagnostic algorithms as applied to onboard computers are considered. Data on the necessary frequency of quantization of some physiological parameters to be fed into the digital computer are presented. Possibilities of machine analysis and logical evaluation of biomedical information are discussed. It is proved that deterministic algorithms can be applied to develop programs for automatic medical monitoring. Some other types of algorithms, e.g., probabilistic, scanning, self-learning, etc., are described. The procedure of programmed biomedical studies involving the onboard digital computer is shown. It is emphasized that the application of algorithm and programming techniques to solve diagnostic problems is of great importance for the development of efficient onboard systems of automatic biomedical monitoring and investigations.

An increase in the duration and range of space flights leads to an appreciable limitation of the possibilities of transmitting information back to earth. At the same time, a significant expansion of the volume of in-flight collected medical information is required to ensure reliable medical monitoring and to solve research problems. This contradiction can be overcome only by creating physiological measuring systems on the spacecraft which incorporate onboard computer devices (V. V. Parin et al.). Such devices, represented by electronic logical systems (V. Ya. Kostikova et al.) and electronic digital computers (R. M. Bayevskiy et al.), have been examined in a number of articles. However, the development of specific onboard diagnostic systems for medical monitoring and investigations is still hampered owing to the lack of appropriate algorithms and machine programs. /69

In this article, we will examine certain principles of constructing diagnostic algorithms applicable to digital computers on board the spacecraft. The following conditions of the use of onboard computers are considered: 1) the input of information is accomplished directly from the astronaut; 2) the possibilities of the onboard computer with respect to memory and speed are quite limited; 3) the onboard computer must solve both the problem of "compressing" the information for transmittal over small-capacity telemeter channels and the problem of automatic evaluation of the astronaut's condition and reporting dangerous states (V. V. Parin and R. M. Bayevskiy, 1963). When developing a diagnostic algorithm it is necessary to study a wide range of problems, including determination of the character of the initial information and methods of presenting it for input into the computer, methods of analysis and evaluation of data, and problems of forming the output signals. An

astronaut with sensors and electrodes and the medical apparatus on board are regarded as the information source.

Since most recordable physiological parameters represent analog quantities, one of the most important parts of the system for automatic processing of medical information, which incorporates the digital computer, is the analog-to-digital converter. Here the problem immediately arises of selecting the quantization frequency. Approximate data on the quantization frequency of some physiological parameters are presented in the table. /70

TABLE. QUANTIZATION FREQUENCY OF PHYSIOLOGICAL PARAMETERS FOR INPUT INTO A DIGITAL COMPUTER

Parameters	Number of necessary discrete readings			
	With Respect to Time		With Respect to Amplitude	
	From	to	From	to
Electrocardiogram.....	100	400	16	128
Phonocardiogram.....	200	2000	16	128
Seismocardiogram.....	100	200	16	64
Electroencephalogram.....	50	50	8	64
Electromyogram.....	400	2000	8	64
Sphygmogram.....	100	200	16	64
Pneumogram.....	10	50	8	32
Thermogram.....	0.003	0.03	32	256

The physiological information can also be represented in a long form as impulses of current or voltage or a series of closing of relay contacts. Such information will be stored in the memory of the computer in the form of numbers characterizing the quantity of impulses in a certain time period or time between impulses. Here, conversion of the type "period-digit" and "frequency-digit" is used. Most physiological parameters can be represented as an impulse. Of course, in so doing only a certain part of the diagnostic signs are reflected in the input information; however, the use of special methods of analysis permit the decrease of informational content of the input signals to be compensated to some extent. Figure shows a number of physiological parameters schematically in an impulse form as well as examples of a histographic analysis of the time intervals between impulses.

Ultimately, the input information is converted to digits which are stored in the high-speed memory of the computer. The primary digital information can later be analyzed by different methods. We can distinguish the three trends in the machine analysis of physiological data: 1) modeling of known methods of

analysis, 2) bionic, 3) mathematical-statistical (Figure 2). The first trend includes methods mainly of amplitude-time analysis, since the determination of time intervals and amplitudes of the waves of various oscillograms and the calculation of a number of indexes are most widely used at present. The medical algorithm of such an analysis is not complicated. However, from the programmer's point of view this is the most complex type of analysis since it requires an exact diagnosis of individual waves and intervals on the curve. The mere detection of prescribed amplitude-time indexes often becomes a most complex logical problem. /71

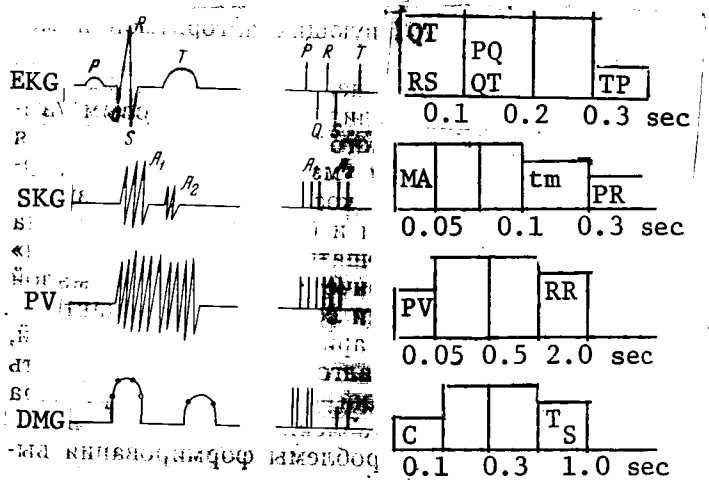

Figure 1. Histographic Method of Analyzing Physiological Information Represented as Impulses.

Time intervals between impulses are analyzed. The boundaries of the histogram classes are selected in conformity with diagnostic requirements. Examples of analyzing the EKG, SKG (seismocardiogram), DMG (dynamogram), and data on PV (pulmonary ventilation) are shown. For the EKG the histogram classes are selected so as to isolate the main time intervals. For the SKG it is possible to determine the pulse rate and mechanical systole (tM) and, during movement, the MA index (motor activity). In the dynamographic investigation it is possible to determine strong squeezes (closing of two contacts of the dynamograph) and weak ones. For PV, with the use of an anemometric sensor, it is expedient to determine both the number of small intervals (ventilation volume) and the number of large intervals (respiratory rate).

The bionic trend encounters the problem of diagnosing models. The machine models the activity of an experimental specialist, who determines from the shape of the curve, without making any calculations, the character of the deviations or sets up the diagnosis. The machine, just like a doctor, compares the presented information with standards stored in its memory. A standard most like the investigated curve is selected, and its number is reported to the doctor-operator.

The mathematical-statistical method of analysis consists of computing a number of purely mathematical indexes and functions. This method of analysis is uncommon for a doctor, but most adequate for a machine. Experience in histographic, autocorrelation, and spectral analyses of a dynamic series of cardiac cycles has shown that mathematical methods of analysis elicit such characteristics of physiological functions as those that require extensive investigations for diagnosis by ordinary methods. For the basis of a mathematical analysis it was possible to construct the algorithm for monitoring the astronaut's condition in the presence of only one parameter -- heart rhythm (V. V. Parin and R. M. Bayevskiy, 1966). /72

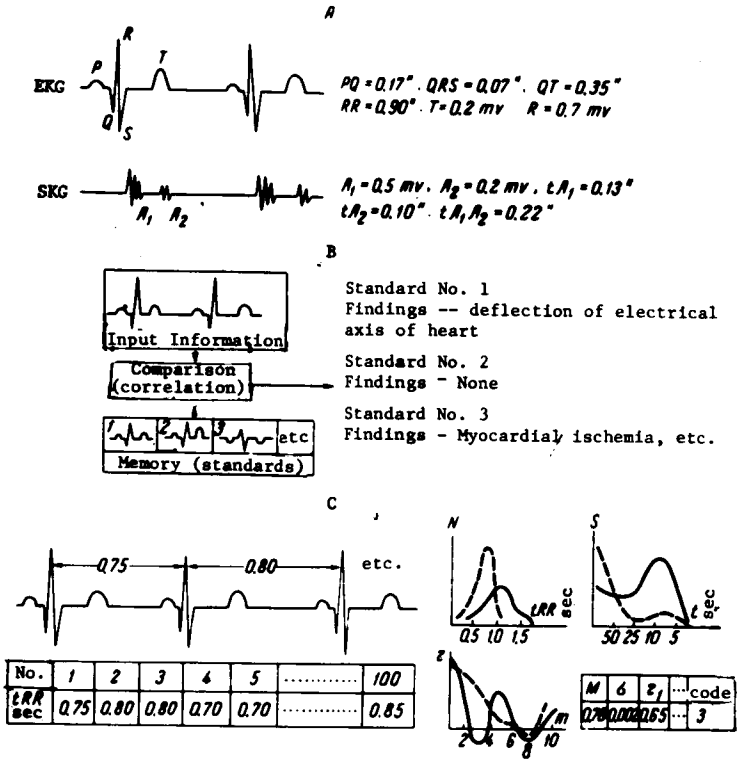

Figure 2. Three Approaches to Automating the Analysis of Medical Information.

A) Modeling of known methods of analysis. Calculation of amplitude-time indexes, such as QT or tA_1. B) Bionic approach -- modeling of the activity of an experimental doctor who diagnoses the characteristic recordings based on their structure (diagnosis by model). The digital computer compares the input information with standards stored in the memory. The number of the appropriate standard or the findings are read out. C) Mathematical-statistical approach. The statistical indexes M, σ, AS, etc. are computed, and a correlation and spectral analysis performed. The information at the output of the digital computer represents values of individual mathematical-statistical indexes or the code of the "state" (based on the sum of the indexes). Specimens of such an analysis are shown for a series of 100 RR intervals of an EKG recorded on a healthy person in a state of wakefulness (solid line) and sleep (dashed line).

These methods of analyzing medical information can be extended to physiological processes recorded both in micro- and in macro-intervals of time. In so doing it is possible to obtain new effective diagnostic criteria. The digital data obtained on quantizing the physiological parameters fed into the digital computer can be subjected to mathematical analysis, for example, autocorrelation analysis as in electroencephalography (V. A. Kozhevnikov and

R. M. Meshcherskiy), spectral analysis such as Scher and Joung are attempting in order to analyze electrocardiograms, etc. In these cases we are dealing with microanalysis. Macroanalysis deals with certain integral characteristics of physiological functions or with their dynamic indexes during a rather long time interval. The daily temperature curve, for example, can be such an index. In investigations of the heart rhythm, considerable interest is now being shown in the so-called slow waves -- changes in the duration of the heart cycles with a period greater than the respiratory period. Interesting data have been obtained on changes in the "slow waves" in astronauts in flight.

A logical evaluation of the data obtained is the most complex stage of the diagnostic algorithm. With respect to the problems of medical support of space flight, we must distinguish the evaluation of the general condition of the astronaut and the detection symptoms and syndromes indicating the degree and character of pathological deviations (medical monitoring) from the evaluation of the state of individual functional indexes with a determination of the changes that have not yet become pathological but which differ from the norms established in ground experiments (medical investigations). Medical monitoring is carried out for a minimum of physiological parameters; therefore, an important role is given to the development of a logical program. The simplest logic consists of comparing the computed indexes with their preassigned values (range of norms) and eliciting the direction and degree of deviation. We code such deviations as "+" or "-" in the presence of quite appreciable deviations from the norm, "T" for relatively insignificant deviations (transitory states) and "N" if the index is within the prescribed range of the norm. The obtained codes "+, -, T, N" constitute certain combinations which are then classed as specific symptoms. For example, an increase in the rate of the pulse and respiration with a decrease in body temperature and arterial pressure is characteristic for shock states; hence, the combination: pulse "+," respiration "+," body temperature "-," and arterial pressure "-" can be classified as shock. This logical program is applicable for evaluating indexes obtained both in amplitude-time and in mathematical-statistical analyses. Figure 3 shows the block diagrams of diagnostic algorithms which we worked out with the participation of K. K. Chernyshev, V. A. Sharov, and B. A. Pryakhin, which illustrate the use of the described logic for medical monitoring of three parameters (electrocardiogram, seismocardiogram, and pneumogram) and one parameter (pulse rate). These algorithms are regarded as quite acceptable for automatic medical monitoring by means of an onboard computer (R. M. Bayevskiy, 1965; V. V. Parin et al.).

Algorithms such as those described above are called deterministic since /73
they require a one-to-one correspondence of the signs to the symptoms and of the symptoms to the "diagnoses." At present, more complex versions of diagnostic algorithms are being worked out: probabilistic, scanning, and self-learning, which are based on a search of the clinical precedent and are related with phase-interval logic, etc.

Let us briefly examine characteristics of such algorithms, bearing in mind the possibility of their use in space medicine. Of interest are the probabilistic algorithms since different conditions (diseases) are distinguished not on the basis of "rigid" combinations but on the greatest probability computed on the strength of knowing the quantity of information contained in each

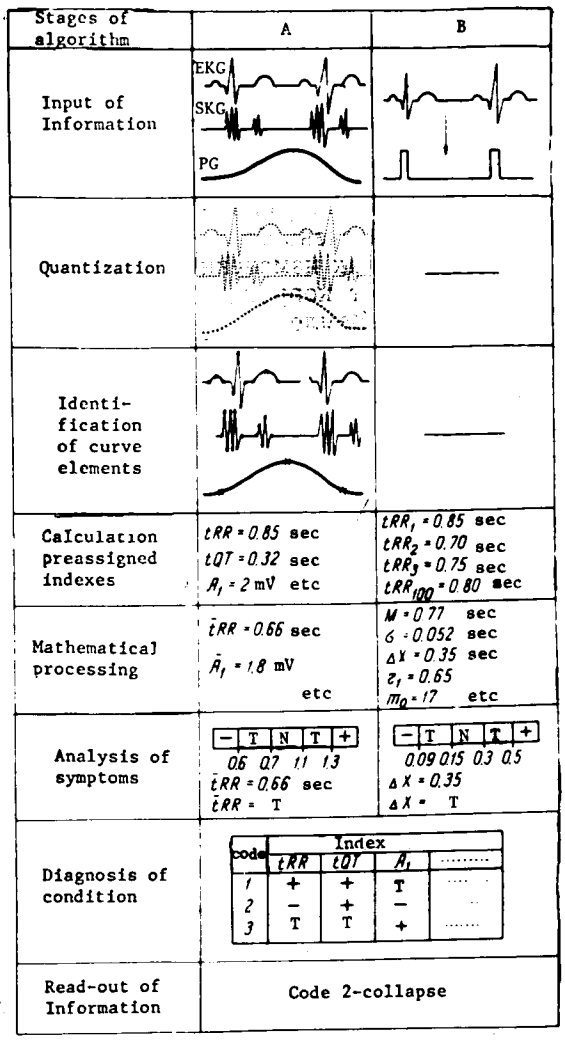

Figure 3. Two Types of Algorithms for Medical Monitoring.

A) Algorithm for medical monitoring of EKG, SKG, and PG (pneumogram).
B) Algorithm for medical monitoring based on mathematical-statistical analysis of data on cardiac rhythm (see also Figure 2, C).

deviation relative to each probable disease (M.L. Bykhovskiy). Phase-space logic is based on presenting the normal and pathological conditions as an aggregate of points in a coordinate system whose axes represent specific parameters of the investigated organism. The algorithm is directed toward establishing the relation between a given point and a certain area. Calculations are performed by means of the set theory (M. L. Bykhovskiy). The algorithms, based on a search of the clinical precedent, compare the set of symptoms observed in a specific patient with the symptom complexes observed earlier in patients with known diseases. In this manner it is possible, for example, to evaluate the condition of an astronaut by comparing him with various conditions recorded during tests and training when simulating the effect of flight factors. The aforementioned bionic method of analysis of oscillograms is to some extent similar to the examined type of algorithms, since a search for the precedent, i.e., a standard most like the investigated curve, is also performed.

Scanning algorithms are of considerable interest to space medicine. They permit construction of a general monitoring program for all phases of the flight from graphs of the changes of prescribed physiological functions. Here, analyses are assigned for each time interval which can be rigorously individualized. The solution to the problem of medical monitoring in this case is reduced to the following correspondence between the current and known dynamics of functions. The most modern are the self-learning algorithms which, with the course of time, can increase their own effectiveness. Self-learning is based on the capacity of the machine to accumulate information and on the presence in the program of certain previously provided principles of correction and improvement of the diagnostic effectiveness of the algorithm.

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The development of self-learning algorithms is extremely important for supporting flights of very long duration (for example, interplanetary flights) since changes in the reactivity of an organism during such a flight require correcting diagnostic signs contained in the program on earth.

The use of an onboard computer for medical investigations is related to the simultaneous processing of several parameters. Such polygraphic recording is especially effective with the simultaneous use of diverse functional tests. This is the so-called programmed research method which was used for the first time during the flight of the spacecraft "Voskhod-1." The programmed research algorithm for an onboard computer has now been worked out and experimentally checked (R. M. Bayevskiy et al.). Three types of output information are possible in programmed medical research by an onboard digital computer: in the form of values of individual indexes (up to 200 digits per 5 min, the research cycle), as generalized evaluations of each individual parameter and each functional test (up to 20 digits), and as an arbitrary code characterizing the result of the entire research or its stages (4-5 digits).

In conclusion, we will list the methods of using the output information of automatic systems of medical monitoring and investigations. Three directions are possible here: 1) transmission of data by telemetry to earth (generalization and condensation of information); 2) display and storage of information on board the spaceship; 3) coupling of the onboard digital computer with the technical systems of the spacecraft -- the incorporation of devices for biological signals (biocontrol and biosignaling).

We have discussed a number of the basic problems of using onboard digital computers for solving problems of space medicine. As is apparent, rather definite steps have been contemplated for developing specific and effective diagnostic algorithms. Now we are in need of a rapid accumulation of experimental and clinical data for checking the different versions of algorithms on digital models with the use of general-purpose electronic digital computers. After the modeling stage we can start compiling programs for onboard computers. At present we can definitely say that the directions being taken for developing algorithms and programming of diagnostic medical problems for a spacecraft computer will undoubtedly soon result in the creation of effective onboard automatic systems for medical monitoring and investigations.

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PROBLEMS OF SELECTING SCIENTIST-ASTRONAUTS

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ABSTRACT. The present stage of development of astronautics necessitates the active participation of highly qualified scientists in space missions. In this connection, space medicine encounters a new problem -- to develop scientific criteria for selecting scientist-astronauts. This problem involves a study of the age of candidates and their physical fitness. This article emphasizes the significance of the multi-faceted examinations using functional tests to elicit both latent pathology and functional limitations of the human body. The paper indicates the importance of establishing a correlation between the state of the central nervous system and functional abilities of the organism during functional tests, as well as the correlation between vestibular stability, optic sensitivity, and the state of the autonomic nervous system.

During a space flight it is necessary to conduct special, rather complex, research studies. Therefore, we are faced with the problem of enlisting highly qualified scientists as crew members. In this connection, space medicine is faced with the new problem of developing the scientific principles for selecting scientist-astronauts. /75

In this paper we will dwell on three problems: the general aspects of selecting scientist-astronauts, age characteristics, and the complex group of investigative methods used in their selection.

Theoretically, there are two possible ways of selecting and training scientist-astronauts. The first way is to select the necessary specialists from among scientific workers in a specified field of knowledge. The second is to select healthy persons from among institute graduates and train them to be scientist-astronauts. At the present stage the first way seems to us to be more expedient.

The selection of astronauts presupposes that the astronaut can endure a space flight while maintaining a sufficient level of performance and that he can successfully fulfill the flight mission. This evaluation is made from an analysis of the conditions of a given space flight and an evaluation of the state of health of the astronaut.

The difficulty in evaluating the state of health of scientist-astronauts is that these persons generally have not been under systematic medical control.

Furthermore, scientists as a rule show various deviations in the state of their health and the level of their physical fitness is usually not optimal. /76

It is quite evident that the ranks of scientist-astronauts should include the most qualified specialists, in connection with which the problem of the age limit (40-45 years) arises. It is well known that the adaptability of an orgahism declines with age and that many vital functions become weak. As a result of this decrease in adaptability the organism becomes more susceptible to certain diseases. Sclerotic lesions of the blood vessels are found more often, especially in scientists (A. L. Myasnikov). Anomalies of refraction are also found in a greater percentage of cases among intellectuals than among representatives of other occupations.

At the same time, maturity has its advantages in predicting the mental state of the candidate. For example, it is well known that the most common, so-called "endogenous" psychoses (schizophrenia, manic-depressive psychosis, epilepsy) mainly occur before 30 years of age, while on the other hand, a number of other mental diseases, such as those related to vascular dysfunction or change of life, i.e., those related to "age," arise primarily after 50-55 years of age. Thus, the 30-40-50 age range is most favorable from the point of view of mental health. Furthermore, there is the well-founded opinion that older persons are able to better tolerate conditions of long isolation and monotonous irritations.

The selection of scientist-astronauts is carried out in stages (polyclinic, hospital). Of greatest interest is the hospital procedure during which a thorough clinical and physiological examination can be made, with the use of functional loads to elicit latent pathology and estimate the functional reserves of the person, with respect to specific flight conditions, in order to predict the reliability of the "man-spacecraft" system.

To evaluate the functional state of the higher levels of the central nervous system it is expedient to use the electroencephalographic method of investigation with functional loads (photostimulation, hyperventilation, caffeine test). This complex not only enables us to obtain data on the frequency-amplitude composition of the bioelectrical rhythm of the cerebral cortex, but also to evaluate the condition of the main nerve processes of the cortex and to establish certain clinical-electrophysiological correlations in cases of latent organic and functional pathologies of the central nervous system. In particular, when functional disorders on the part of the autonomic nervous system are elicited in subjects, we can often record theta and delta rhythms of some degree of intensity in the bioelectrical potentials of the anterior regions of the brain.

To evaluate the functional state of the cardiovascular system and to reveal the adaptability of an organism to various kinds of effects, it is proposed that physical exercise, the orthostatic test (G. P. Mikhaylovskiy), and the hypoxic test be used. Investigations on a bicycle ergometer are most informative. Functional tests, in particular physical exercise, permit

the level of physical fitness of most subjects to be elicited (T. V. Benevolenskaya et al.).

When evaluating functional tests, one notes that there is a definite correlation between the state of the central nervous system and the functional abilities of the organism. A pronounced impairment of adaptability to physical exercise is generally observed in subjects with functional changes in the nervous system, most often in the form of neurocirculatory dystonia. The inadequate physical training of the subjects is also of definite significance. We can assume that the sum of these two factors together with dysfunction of the autonomic nervous system is the cause of impairment of adaptation of the cardiovascular system to physical exercise. /77

A correlation between orthostatic stability and hemodynamic indexes, as well as with rhinopneummetric data, has also been established (N. Ya. Yakovleva and V. P. Baranova). Poor tolerance to orthostatic effects is observed against a background of a decrease in the peripheral resistance of the vascular network and an increase in the cardiac output, rate of cardiac ejection, and intranasal resistance (V. P. Baranova, T. V. Benevolenskaya et al.).

When investigating the otorhinolaryngological organs, particular attention should be devoted to the functional state of the vestibular and auditory analyzers. For this purpose, it is proposed that we use the OR_{10} test, investigations on a Khilov swing, determination of tolerance to the accumulation of Coriolis accelerations, investigations on a couch with an unstable support, cupulometry, etc.

A comparison of vestibular stability based on the above-indicated methods with the cupulometry data shows that contradictory data are generally obtained in such an investigation. The greatest number of concurrences in evaluating all tests are obtained for persons with high vestibular stability. The main cause of the contradictory nature of the data apparently lies in the dissimilar conditions of stimulation of the vestibular apparatus. Consequently, an examination by means of various methods gives the most complete picture of the person's vestibular stability. There is a definite correlation between vestibular stability, light sensitivity of the eyes, and indexes of the condition of the autonomic nervous system; for example, poor tolerance to vestibular tests is accompanied by a drop in the level of ocular light sensitivity (V. P. Baranova, M. P. Kuz'min, T. A. Petrova) and is usually observed in persons with vasculo-autonomic instability.

The proposed complex method of examination permits the significance of the functional state of the central nervous system, particularly its autonomic division, to be elicited. When the latter is disturbed, adaptation mechanisms suffer, as demonstrated by a functional change of some system of the organism. Investigations and observations of persons of different ages and specialties suggest that it is not so much the age as the functional abilities of the astronaut and his professional worth that should be decisive in selecting scientist-astronauts.

It should be indicated, in conclusion, that this material does not claim to be complete and certainly does not touch upon all aspects of this problem.

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PREVENTION OF THE ADVERSE EFFECT OF HYPOKINESIA ON THE HUMAN CARDIOVASCULAR SYSTEM

P. V. Buyanov, A. V. Beregovkin, and N. V. Pisarenko

ABSTRACT. Prevention of the adverse effect of the hypokinesia inherent in prolonged space missions on the human cardiovascular system is discussed. On the basis of the literature and their own data, the authors prove the effectiveness of procedures for maintaining good physical fitness at a sufficient functional level of the circulatory system. The procedures involve adequate physical training and rhythmic compression of the limbs. The use of pharmacological agents and moderate hypoxia for the same purpose requires further investigation.

The small volume of a spacecraft appreciably restricts the movement of an astronaut. The effect of hypokinesia on the astronaut is aggravated by weightlessness which eliminates, to a considerable extent, the need for muscular effort to avert changes in body posture and to move about in space. /78

Most investigations into hypokinesia have been carried out in small pressurized chambers simulating the cabins of spacecraft. For a more rigorous limitation of movement, subjects have been placed in plaster-of-paris casts while wearing flight suits and space suits, or have been restrained on special stands. Investigations involving simulation of weightlessness by submerging the person in a horizontal position in various media have also become common.

Current experimental data enable one to distinguish various adverse effects of hypokinesia and to note, primarily, its effect on the functional state of the human cardiovascular system. Tachycardia has been most persistently observed (Taylor; A. D. Seryapin; A. G. Kuznetsov et al.; L. I. Kakurin and Yu. N. Tolarev; P. V. Buyanoy, and others). Noted regularly are a drop in arterial blood pressure (P. V. Buyanov et al., 1966, and others); changes in the EKG (Graveline and Barnard; N. A. Matyushina and L. A. Korolev, and others); loss of arterial and venous tone (P. V. Buyanov, and others), and a decrease in the stroke volume and cardiac-output with an increase in peripheral resistance (A. V. Lebedinskiy et al., and others).

These disturbances on the part of the circulatory system are the main cause of the decreased endurance of the cardiovascular system to physical stress and orthostatic disturbances (Lamb and Roman; Graveline and Barnard; P. V. Buyanov et al., and others).

Some authors (Lamb and Roman, 1961) relate the changes in the cardiovascular system to disturbance of the reflex mechanisms regulating circulation and redistribution of blood through various vascular regions and to an altered reactivity of the central nervous system as a whole. Considerable importance is /79

also given to the state of the skeletal muscles (A. V. Korobkov, 1965; L. I. Kakurin et al.; B. K. Panfilov).

The dissimilar explanation for the mechanisms of disorders in the circulatory system arising during prolonged restriction of movement was the reason for the varying preventive recommendations. A. V. Korobkov (1965) places strong emphasis on physical training and maintaining physical fitness under conditions of restricted movement. Some American authors, skeptical about the usefulness of physical exercise, consider compression of the limbs to be most effective or recommend a combination of physical exercise with the use of intermittent compression of the limbs which guarantees the normal vasometer activity of the veins.

Vogt and Johnson, as a preventive measure against the conditioning effect of hypokinesia, have successfully used compression cuffs on the limbs in which a pressure of 60 mm Hg was rhythmically produced at up-and-down intervals of 1 min. Lamb proposes the use of moderate hypoxia to combat the aftereffects of hypokinesia.

Taking into account the contradictoriness of the available data, we carried out clinical physiological investigations designed to study the effect of hypokinesia on the human cardiovascular system and to evaluate certain preventive measures in experiments set up by V. I. Slesarev. The duration of hypokinesia was 10-12 days. Thirteen healthy males, 22-26 years of age, participated in 17 experiments. The subjects were placed on a special stand in a posture corresponding to the maximal relaxation of the muscles, in a position close to horizontal.

Three series of investigations were performed: the first without the use of protective agents; the second with periodic compression of the lower limbs by means of an antigravity suit*; and in the third series a complex of physical exercises was used before, during, and after hypokinesia.

The hemodynamics were studied by recording the arterial oscillograms and tachooscillograms and by polygraphic recording of the phases of the cardiac cycle. The passive orthostatic test and graduated physical loads were used as functional tests.

Hemodynamic studies carried out during hypokinesia revealed disturbances that were the result of adaptation of the circulatory system to the changed environmental conditions. A diminution of metabolic processes, a decrease in the stroke volume and cardiac output, a loss of vascular tone, and a moderate drop in arterial pressure were observed.

The most obvious changes during the period of transition from hypokinesia to activity were noted in the first series of observations. During the first 5-6 days after the end of the experiment we noted instability of the arterial

*Every 1-2 hr a pressure of 60-75 mm Hg was produced in the suit for 10-15 min.

pressure, cardiac output, and vascular tone. An electrocardiographic investigation revealed pronounced tachycardia, shortening of the P-Q interval, lengthening of the QRS complex, and a drop in the voltage of the sum of waves K1-3 and T1-3. On the ballistocardiogram we noted a decrease in the waves of the systolic complex and an increase of the diastolic waves. A phase analysis of the cardiac cycle revealed lengthening of both the period of strain and period of ejection, and also an increase in the ratio of the time of mechanical systole to electrical systole (by 4-20%).

The most distinct alterations were found in functional tests. A passive change of body position from horizontal to vertical caused, in all subjects, general weakness, heaviness in the lower limbs, and sometimes dizziness. Cyanosis of the skin and swelling of the veins of the lower legs were noted. Fainting occurred in one case. The increase in the pulse rate was more pronounced in comparison with the initial level (+44%). The stroke volume dropped appreciably. The cardiac output also diminished by 37% on the average, despite noticeable tachycardia. A loss of vascular tone was often found. We observed a more pronounced rise in diastolic pressure with a simultaneous drop in the lateral pressure and sometimes also the average dynamic pressure, which led to an appreciable decrease in pulse amplitude. When the subject was changed to a horizontal position the hemodynamic indexes were restored to normal after a brief delay. /80

During application of graded physical loads, the changes were manifested in two well-defined forms. The first was characterized by retention of the same directivity of the main hemodynamic indexes as before the experiment; however, the quantitative shifts were more pronounced. In the second form the hemodynamic shifts were distinguished by a smaller increase in the heart rate; the pulse pressure and stroke volume decreased. This "paradoxical" reaction to physical stress indicated appreciable functional disorders in the circulatory system. In one subject with this type of reaction, fainting was observed at the moment of physical exercise.

In the second series of observations under resting conditions, we did not observe any appreciable difference in comparison with the control examination. The changes in the EKG were less obvious than in the first series: the voltage sum of the K and T waves dropped negligibly, and the systolic index did not exceed normal values.

For most of those examined in the second series, objective indexes made it possible to establish a better tolerance to the orthostatic test than in the first series. The pulse rate increased to 108 per minute on the average (as opposed to 118 in the first series). The stroke volume decreased by 12% (in the first series, by 56%). The cardiac output increased somewhat. However, the use of compression did not always ensure functional adequacy of the circulatory system -- one subject fainted after standing 3 minutes.

The direction of the hemodynamic alterations during physical exercise were the same as in the initial state. There were no cases of "paradoxical" reaction of the cardiovascular system to physical exercise in this series.

After conducting the third series of experiments, we found a 20% decrease in the stroke volume under resting conditions. The cardiac output was 17% lower than before the experiment. Other indexes did not differ from the initial value. The reaction of the circulatory system to the orthostatic test and physical exercise did not differ from the control reaction.

The results of our investigations give a basis for concluding that compression and physical exercise are effective in preventing the unfavorable effects of hypokinesia on the cardiovascular system. Better results were obtained, however, by physical training methods.

There is no doubt that physical exercise plays a role in preventing a loss of muscle tone which is of definite value in venous return. However, in our opinion, mere maintenance of physical fitness during long space flights does not produce desirable results. The clinical physiological examination /81
which we conducted together with V. G. Terent'yev after three men spent 70 days under conditions of restricted motor activity but with maintenance of physical fitness, by means of a special set of exercises, revealed distinct signs of loss of function of the cardiovascular system, particularly a decreased tolerance to the orthostatic test as a result of impairment of arterial and venous tone. Therefore, under conditions restricting motor activity, it is expedient to use a complex of measures in which maintenance of physical fitness is combined with effects directed toward preserving vascular tone, in particular rhythmic compression of the limbs. Frequent rhythmic compression is a more adequate stimulus for tissue and vascular receptors than infrequent compression.

Lamb's proposal to use the periodic effect of moderate hypoxia is also noteworthy. It is well known that hypoxia is accompanied by a redistribution of the blood over various vascular regions, which is primarily associated with differently directed changes in vascular tone: a decrease in tone of the cerebral vessels (Kety and Schmidt) and an increase in tone of the vessels of the extremities (Bauereisen; Abramson et al.; Ye. S. Diligenskaya).

According to our data (P. V. Buyanov et al.), based on analysis of 138 experiments*, hypoxia leads to an enhancement of vascular tone which is indicated by the dynamics of the propagation velocity of the pulse wave over muscular and elastic vessels. In persons with a low initial vascular tone, the hypertonic reaction is evidenced more distinctly in comparison with subjects having a normal or high tone. The ratio of the propagation velocity of the pulse wave over muscular (C_m) arteries to the velocity over elastic (C_e) arteries in persons with a high vascular tone remains practically unchanged in hypoxia. In a group of subjects with a low arterial tone, C_m/C_e increased 10.4% with a high statistical significance ($P < 0.01$).

The data obtained necessitate a serious study of the use of moderate hypoxia in preventing disorders of vascular tone during long space flights. We can postulate that the favorable effect of physical exercise is definitely related to physiological hypoxemia.

*Breathing gas mixtures containing 9.1-10.9 and 8-8.5% oxygen.

Although the use of pharmacological agents before ending a long space flight and landing would obviously be effective, the question of the effect of drugs on vascular tone has been inadequately developed. An experimental study of some drugs for stimulating the natural compensatory-adaptive mechanisms and, in particular, vascular tone in order to increase resistance to individual extremal flight factors (transverse accelerations) has yielded reassuring results. Stimulants (dexedrine), the use of which is recommended to American astronauts before landing, are also of value for maintaining vascular tone. An advantage of drugs is the possibility of purposefully acting at all levels of reflex regulation of cardiac activity and vascular tone.

Thus, the data obtained by Soviet and foreign authors even now permit measures to be worked out directed toward maintaining the functional state of the circulatory system, which is necessary for eliminating the adverse effects /82 on an organism of prolonged restriction of movement in combination with weightlessness.

The use of physical exercise and rhythmic compression of the limbs should be the first among these measures. The use of drugs and hypoxia requires further study.

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CURRENT EVENTS

NIKOLAY NIKOLAYEVICH SIROTININ

(70th Birthday Anniversary)

On November 26, 1966, Prof. Nikolay Nikolayevich Sirotinin, Active Member of the Academy of Medical Sciences of the USSR, Honored Scientist, and Doctor of Medical and Biological Sciences, celebrated his 70th birthday. One of the most outstanding Soviet pathologists, Sirotinin's scientific activities have won wide recognition both at home and abroad. /83

Sirotinin began his scholarly and pedagogic career under the mentorship of A. A. Bogomolets, the finest traditions of whose school he was brilliantly to perpetuate and develop in subsequent years. Terminating his studies at the Department of Medicine of Saratov University in 1924, Sirotinin worked until 1929 at the Laboratory of General Pathology, first at Saratov and later at Moscow University. During the period from 1929 to 1934, along with his intensive activity in the area of scientific research, Sirotinin, in his capacity as Director of Pathological Physiology of the Kazan Medical Institute, was also actively engaged in the field of teaching. From 1934 until the present day, he has been at the head of a laboratory and department at the im. A. A. Bogomolets Institute of Physiology in Kiev.

During the early period of his scientific career, N. N. Sirotinin devoted his attention primarily to problems of comparative pathology, in particular to the area of allergy, anaphylaxis, and immunology. Even in these earlier works there is a clear definition of one of the remarkable features of Sirotinin's creative thinking - his evolutionary approach to the solution of problems regarding the specific mechanism of pathologic organic reactions. Professor Sirotinin's fundamental research into the uniqueness of the reaction of the reticuloendothelial system and into changes in the composition of the blood during various anaphylactic stages was not only marked by originality and freshness of concept at the time of its execution but has preserved its significance and interest even to the present day.

Any discussion of this period of the celebrant's career would be incomplete if it failed to take note of the fact that the basic postulates formulated by Professor Sirotinin at that time are at the very heart of contemporary views on the phylo- and ontogenesis of various immunological reactions of the organism. These works are of extraordinarily great importance to a proper understanding

of the complex pathophysiological changes which take place in the organism during many infectious processes and their treatment.

One of the most important medical problems, which has been at the focal point of Prof. Sirotinin's attention for many years, is that of oxygen insufficiency, both at the level of general medical practice and especially as it relates to aerospace medicine. A distinguishing characteristic of the work of Prof. Sirotinin and the team of staff workers and junior assistants under his direction is their broad-based biologically-grounded approach to this problem together with a profound analysis of its most essential aspects. The celebrant's well-known book "Zhizn' na vysotakh i bolezn' vysoty" ("Life at High Altitudes and Altitude Sickness") is a direct outgrowth of this research.

Continuing the finest traditions of Soviet medicine, N. N. Sirotinin has consistently tried to uncover the mechanisms governing the disruptions of particular organic functions at various stages of phylogenesis, in addition to the peculiarities of its different adaptive mechanisms. He and his school clearly established that as the organism develops in onto- and phylogenesis, /84
the increased sensitivity of the central nervous system is accompanied by a concomitant improvement in the adaptive mechanisms. The logic of this research led to the formulation of new tasks; the use of the adaptive reactions of the organism, developed during hypoxia training, for the elimination of a number of pathological processes or for significantly increasing the stability of the organism in the face of various extremal factors.

On this basis, research was initiated into various forms of organic adaptation, in pressure chambers as well as under natural high-altitude conditions. Prof. Sirotinin's irrepressible enthusiasm, indefatigable energy, and impressive scholarship ultimately led to what was, in effect, the creation of a new branch of science - high-altitude physiology. At his initiative and under his immediate supervision, annual expeditions have been made for several decades to the mountains of the Caucasus, Tien-Shan, and the Pamirs. The installation of medical laboratories and high-altitude stations on Mt. El'brus - the highest peak in the Caucasus - was in response to the Professor's urgings. In the summer of 1966, the world's highest mountain laboratory was erected, by means of a helicopter lift, on the eastern summit of El'brus, in the crater of a now extinct volcano, where under severe conditions and at an altitude of more than 5,500 meters Prof. Sirotinin and his staff began studies into the problem of oxygen starvation.

Among the celebrant's achievements is the proposal and refinement of the so-called phased acclimatization principle, that is, the principle of gradual adaptation to mountainous conditions. Under his guidance, the treatment of victims of bronchial asthma, anemia, and certain mental disorders under the high-altitude environmental conditions of the El'brus region has begun, and this form of therapy has been found to be highly effective in many instances. Prof. Sirotinin's ideas have long been used by physicians engaged in the field of athletic medicine in the training of skiers and mountaineers.

For many years, N. N. Sirotinin has been interested in the effect on the human organism of both low and high partial oxygen pressure, various gas

components, the non-pulmonary introduction of oxygen into the organism, reanimation, the physiology of aging, and a number of other problems.

During the last decade, Prof. Sirotinin has been engaged in a detailed analysis of various aspects of space biology and medicine. It should be noted that, even before the commencement of the space era, the celebrant had carried out much fruitful research into different types of oxygen insufficiency encountered during high-altitude flights, with particular attention to the dynamics of partial oxygen pressure in alveolar air, the properties of blood, adaptation and respiration mechanisms, and the pathogenic effect of various forms of accelerational stress.

In recent years, Prof. Sirotinin and his staff have been developing a radically new approach to the study of hypoxia by means of detailed investigation of organic functions and oxygen tension dynamics in various tissues under the influence of extremal space-flight factors. This research is uncovering fundamentally new and important facets indicative of the importance of the basic etiological factor of hypoxia - that is, the oxygen tension level - in the face of acceleration. Prof. Sirotinin is also the author of the idea that a significant increase in the human organism's ability to withstand G-forces and other extremal space-flight influences can be achieved through phased acclimatization in mountainous environments.

Nikolay Nikolayevich Sirotinin is a bold, courageous, and dedicated experimenter who, at critical and dangerous moments, has more than once not hesitated to carry out tests on his own person. The seminars and conferences convened by Prof. Sirotinin on the problem of oxygen insufficiency have become tradition in our country. These meetings, which are attended by the nation's leading scientists, provide an excellent forum for thorough, in-depth discussions of the most varied aspects of this universal medical problem.

The editorial staff of the journal "Kosmicheskaya biologiya i meditsina" ("Space Biology and Medicine") takes this occasion to extend to Nikolay Nikolayevich Sirotinin heartfelt best wishes on his 70th birthday, and to wish him good health and new creative accomplishments in the service of our nation.

RESULTS OF THE XV INTERNATIONAL CONGRESS ON AEROSPACE MEDICINE

F. P. Kosmolinskiy and I. M. Khazen

The XV International Congress on Aerospace Medicine was held in Prague from September 26 through October 1, 1966. More than 250 reports were delivered at the congress, with delegates from 32 countries participating. The largest representation was from Czechoslovakia and included some 100 members. Other large delegations represented the USSR (50 members), the United States (37 members), France (30 members), and Poland (28 members). The Soviet delegation was headed by Academician V. V. Parin. /85

No individual sessions by section were held at the congress, so that all the meetings were plenary sessions. This method of organizing the congress

cannot, in our opinion, be considered altogether satisfactory. At each session, one or two basic reports were read, lasting anywhere from 30 to 90 minutes. On the other hand, only 5 minutes per paper were allotted to the vast majority of speakers. In this amount of time, only the most general notion of the contents of the paper could be acquired - a fact which could not help but be reflected in the assessment of the material presented, no discussion of which, in effect, took place on the floor of the congress. Only outside the hall were the delegates able to acquire some further familiarity with the substance of the reports.

The following fundamental problems were discussed at the congress:

- the effect of flight-related factors on the human organism, and adaptation to them;
- age-associated peculiarities and the occupational pathology of flight crews;
- spatial orientation;
- radio-biological protection of astronauts.

A majority of the reports dealt with the problem of the physiological adaptation of the human organism to varied and complex environmental conditions during flights on various modern flying craft. Serious attention was focused on the problem of the recording of physiological functions under in-flight conditions. For example, this problem was the subject of a report by V. V. Parin and R. M. Bayevskiy (USSR), which contained an exposition of the cybernetic aspects of space physiology and an outline of the basic principles of systems design for the recording of physiological functions and the processing of received data.

A paper by Ruffel-Smith and Patrick (Great Britain) dealt with the use of a special sensor vest for the recording of physiological functions (pulse, respiration) of commercial pilots flying the London-Milan route. The authors recorded maximum pilot stress during landing and take-off (with pulse rates as high as 120 and 102/min, respectively).

The flight stress problem was touched upon in a number of other papers as well. L. S. Isaakyan (USSR) also presented data on maximum pilot stress on landing and take-off. The author called attention to the fact that emotional reactions are noticeably lower in the case of experienced pilots above 40 years of age. Decreased stress reaction is a function of both the age and the experience of the pilot, the second factor being of greater importance in the development of emotional stability.

H. Wissfeld (Fred. Rep. of Germany) emphasized the need for design improvements in the aircraft landing process and for the creation of more comfortable working conditions for the pilot in the cabin.

A report by P. K. Isakov (USSR), dealing with the physiological mechanisms of human adaptation to extremal influences under experimental conditions, contained data on unique conditioned-reflex responses to stress. In the author's opinion, preliminary familiarization with anticipated effects and verbally

imparted information regarding them give rise to a kind of stress reaction on the part of the organism involving the physiological mechanisms of anticipatory reactions and, in effect, only a single conditioned-reflex reinforcement. The organism's functional state and its stability can then be modified in whatever direction required by means of certain pharmacological agents. Thus, for example, ingestion of chlorpromazine results in improved reactions to the effect of such factors as ejection training.

Ruff (US) read a report on the psychological adaptation of astronauts during flights in the "Mercury" spacecraft. The individual characteristics of the astronaut, the quality of his training, and his flying background are of great importance in analyzing flight-associated stress reactions. In the case of experienced pilots, emotional reactions to flight are below maximum permissible values and are completely compatible with the requirements of flight safety. /86

P. V. Buyanov and V. G. Terent'yev (USSR) presented interesting data on the clinico-physiological aspects of extended space-flight reliability prediction from the viewpoint of possible illness on the part of the astronauts during flight. In this same connection, the authors submitted astronaut selection charts based on medical criteria. In the opinion of these writers, the basic condition underlying the ability of the human organism to withstand space-flight conditions is stability of the cardiovascular and central nervous systems.

A scholarly analysis of the complex mechanisms of the regulation, adaptation, and compensation of functions during periods of acceleration was presented in the reports of A. S. Barer (USSR), Zilek and Trojan (Czechoslovakia), Ye, F. Kotovskiy (USSR), P. V. Vasil'yev (USSR), I. M. Khazen (USSR), Zseton and Sarol (Poland), and others.

Due attention was paid to the problem of hypoxia and adaptation to it. Thus, in a joint paper, N. A. Agadzhanyan, A. G. Kuznetsov, and V. V. Parin (USSR) pointed out the effectiveness of training in elevated mountain regions for enhanced organic resistance to various extremal conditions. According to data supplied by these authors, the favorable effect of such mountain training persists for 22 to 26 days.

The problem of improved organic resistance to flight stress-factors by means of adaptation to lowered barometric pressure was the subject of reports by a number of Soviet writers (P. V. Vasil'yev and V. B. Malkin; V. A. Isabayeva; M. M. Mirrakhimov).

In his paper, Zsmigelski (Poland) discussed changes in the activity of various blood enzymes and in the over-all structure of the blood during hypoxia. Variations in dehydrogenase, catalase, and carbonhydrase activity, as well as the increase in lactic acid in the erythrocytes with elevated erythropoiesis and hematocrit during hypoxia, are adaptive in character.

The congress listened with considerable interest to the report of von Beck (US) on the problem of explosive decompression and the search for a way of

increasing the resistance of the human organism to decompression under space-flight conditions. Tests with chimpanzees at atmospheric pressure gradients from terrestrial values to an almost total vacuum disclosed that decompression with an exposure of 5 to 20 seconds duration gives rise, in simian organisms, to functional changes which, despite loss of consciousness in the animals lasting from 2 to 2.5 minutes, are reversible in character. The author showed a brief color film illustrating his experiments.

A report summarizing the medical support data for the "Mercury" and "Gemini" space flights was presented by Berry (US). The speaker described the functional condition of the astronauts during the flight and gave an assessment of their ability to perform work both within the capsule and in outer space. Emphasis was again placed on the importance of ensuring retention by the astronauts of the necessary capacity for work under various extraterrestrial environmental conditions. The author dwelled in detail on a description of the changes in the metabolic processes of the astronauts, particularly the water-salt and protein metabolism. In the opinion of this investigator, biochemical changes depend on a number of causes: limited mobility, alimentary changes, respiration of a gaseous mixture with a high oxygen content, etc. It was also noted that by properly scheduling the activities and rest of the astronauts, sufficient capacity for useful work can be ensured. Thus, for example, the daily schedule for the crew of "Gemini 7" approximated normal conditions characteristic of life on Earth, with improved nourishment. As a result, anomalies in the organic condition of the astronauts, under the influence of a two-week flight, were less pronounced than anticipated. Berry's report was accompanied by the showing of color films dealing with ground training of astronauts and the execution of various work activities in free space.

Both in Berry's report and in a number of other papers (Campbell and Graybill of the US), the thought was expressed that the time has come to review the question of the role of the vestibular apparatus in the development of autonomic disturbances and in the causation of a feeling of illness on the part of astronauts in flight. It is the view of these authors that, under conditions of weightlessness, the principal cause of changes in the functional state of the organism should be sought in extralabyrinthine reactions, while in the case of well trained pilot-astronauts vestibular reactions have no effect on the ability to perform work and can be detected only with difficulty. This viewpoint is in agreement with the previously expressed opinion of a number of Soviet writers. Various kinds of illusions observed during flight are a function, in the opinion of the American researchers, mainly of hemodynamic reactions and, specifically, of changes in blood flow in the vessels of the brain.

Several reports dealt with the ability of humans to perform work in free space. According to data presented by P. V. Vasil'yev (USSR), the space walk of A. Leonov was accompanied by considerable stress. His pulse, for example, was at a level of 148-150 per minute, rising to 162 per minute during re-entry into the capsule. Respiration increased to 36 per minute. Nervous tension and heightened motor activity also led to an increase in body temperature to 37.6°C. /87
The "Voskhod-2" space mission demonstrated man's ability to exist and work in

free space. The excellent preliminary preparation and training of the astronauts ensured that they would be capable of performing work assignments satisfactorily during the flight.

Berry (US) delivered a paper containing information of considerable interest with respect to extra-vehicular activity by astronauts. Work performance in outer space is a difficult matter. Every movement results in a whole series of "counter-movements," and coordination is disrupted. As a consequence, R. Gordon ("Gemini 11") required 30 minutes to complete the operation of joining the capsule to a target rocket instead of the 30 seconds required during training in an "agravity pool" installed in the fuselage of an aircraft traveling along a Keplerian parabola. At the same time, his energy consumption was far in excess of the theoretical rate. The astronaut tired rapidly, his temperature rose, his pulse quickened to 160 per minute and his respiration increased to 40 per minute. His pulse rate had risen to 180 per minute by the end of the assignment.

The urgent problem of vocational flight crew pathology was the theme of considerable discussion at the congress. Protracted flights at high speeds and great altitudes levy increasingly severe requirements on the organic constitution of the pilots of present-day aircraft. With the passing of time, the enormous strain to which the pilot's central nervous and cardiovascular systems, autonomic functions, and emotions are subjected ultimately leave their mark on the individual's health. For this reason, the study of the age-related pathology of flight personnel takes on great importance from the point of view of both the preservation of crew health and flight safety.

In a report by McFarland (US), an analysis was made of the flight personnel of several American airlines from the standpoint of age. While only 17.4% of all pilots fell in the age group from 50 to 60 years of age in 1964, figures show that by 1974 65.2% of all pilots will be in this category. According to the author's data, in those airline companies where medical service is best organized, fewer pilots are retired from flight duty and there are fewer accidents. From this follows the need for improved medical services and more adequate medical examination of flying personnel. It is the author's view that analysis of a number of the pilot's psychological traits provides an excellent basis for predicting his skill as a flyer. The pilot's motor reaction speed should be a subject of primary concern and study. Stricter medical certification should be introduced for pilot personnel above 40. In this connection, however, the speaker noted that of 107 American airlines, only 37 use modern methods of medical supervision and flight crew selection.

A very significant paper on the same subject was delivered by A. N. Babiychuk (USSR). This speaker pointed out that as the age and service time of pilots increase, a greater tendency toward disorders of the cardiovascular system (arteriosclerosis, hypertension) can be observed. Pilots above 40 also demonstrate a tendency toward excess weight. Spondylosis and varicose veins are not uncommon in pilots in the 40-to-45 year age group. However, along with age, professional experience is also acquired; the pilot becomes more prudent and better balanced - factors which compensate completely for certain deficiencies which may exist in his health. The author therefore believes that in the

medical certification of pilot personnel, consideration should be given not to the subject's age, but to his individual characteristics, his professional background, and his actual ability to perform his job. This same viewpoint was expressed by Chornowski and Zakrewski (Poland).

Kidder (US) also took notice in his report of the increase in cardiovascular and endocrine diseases in pilots above 40 years of age.

A. I. Kravtsov and L. S. Isaakyan (USSR) presented data on the age variations of the cardiovascular system in civil airline pilots. For instance, arteriosclerosis in pilots above the 40 year age group is twice more frequent than that of persons of the same age group in other professions.

Similar data, but on the basis of a pathoanatomical analysis, were presented in the report by Vorel (Czechoslovakia).

Several Soviet authors discussed, in their papers, the study of the physiological functions of long-distance pilots (V. V. Rassvetayev; G. I. Gurvich; V. A. Sergeyev; F. P. Kosmolinskiy, and others). These speakers called attention to significant functional anomalies in the cardiovascular and nervous systems after flights lasting many hours. Moreover, extreme fatigue is observed not only in the pilots but also in the other members of the crew.

On the problem of orientation in space, reports were read which dealt with the study of the biomechanics of human motion in a changing gravitational field (L. V. Chkhaidze, USSR), the physiological aspects of artificial gravitation in a spacecraft (M. D. Yemel'yanov et al., USSR), and also the functions of the vestibular apparatus (V. I. Kopanev et al., USSR; Bourget, France; Novotny, Czechoslovakia; Reinberg, German Democratic Republic; and others).

Campbell (US) attempted a reappraisal of the phenomena of illusion and disorientation encountered during space flights and their simulation. This author holds that illusions are not caused by weightlessness, and that the illusions themselves were, apparently, not clearly defined and may have been traceable to a number of causes, including a feeling of illness (disrupted rest schedule), the unusual setting of the flight, etc. Campbell considers it necessary to ascribe greater importance to the selection of astronaut candidates having no sensitivity to illusions. A possible criterion which might be used in such selections is flying experience (not less than 1,000 hours of flying time in jet aircraft). /88

Problems of radiobiology were also the subject of considerable attention at the congress. Among other things discussed in this connection were the general principles of dosimetric control under space-flight conditions (Yu. A. Akatov et al., USSR).

K. Klemedson (Sweden) spoke about sources of radiation hazard during space flights and the operation of supersonic passenger aircraft traveling outside the atmosphere. These sources are galactic cosmic radiation, the corpuscular radiation of chromospheric explosions on the Sun, and the emission originating from the radiation belts of the Earth. The primary danger, in the speaker's opinion, is caused by solar radiation.

In the paper written by Yu. G. Grigor'yev and Ye. Ye. Kovalev (USSR), an analysis was made of the problem of the radiobiological assessment of the radiation hazard to space travel and of the question of astronaut protection. In the opinion of the authors, the effect of ionizing radiation, in concert with other flight-associated factors (protracted weightlessness, changeable gas environment composition, unique life-support conditions in the spacecraft cabin, etc.), may have a substantial effect on the final radiobiological outcome. Provision should be made for the creation of a space radiation security system, including such techniques as over-all protection of habitable compartments, radiation shelters, local individual astronaut protection, and pharmacological means of prophylaxis.

In view of the fact that during future interplanetary flights the corpuscular radiation of solar flares will acquire special importance, a number of reports were devoted to an analysis of the results of studies dealing with the biological effects of high-energy protons (N. I. Rhzhov et al., V. M. Seraya et al., USSR).

It is difficult, in a limited review, to cover the entire range of subjects discussed at the congress, much less all the reports that were read. If one were called upon to provide a general estimate of the meeting, he would certainly conclude that the problem area within the over-all realm of aerospace medicine has expanded enormously in recent years and that the research itself has unquestionably taken on added depth. The need to ensure the required support for future long-range interplanetary flights makes mandatory, at the present time, that much work be carried out in the analysis of the vast body of data that has been accumulated by specialists in space biology and medicine.

In conclusion, a word of thanks is due those Czechoslovak colleagues who took upon their shoulders the difficult task of organizing this congress and seeing it through to a successful conclusion. A memorable impression was created by the ceremonial opening of the congress in the old auditorium of Charles University, the Carolinum, the reception held by the mayor of the city of Prague in a town hall dating back to medieval times, and the reception by the chairman of the congress and the administration of the Czechoslovakian airlines in the Waldstein Palace. All these meetings transpired in an atmosphere of warmth and cordiality, thus promoting closer contacts between scientists of different nations and the establishment of a sense of mutual understanding between them.

A decision was reached to hold the next, XVI, International Congress on Aerospace Medicine in Lisbon during September of 1967.

XVII CONGRESS OF THE INTERNATIONAL ASTRONAUTICS FEDERATION

V. M. Mastryukova

The International Astronautics Federation held its most recent (seventeenth) congress in Madrid from October 9 through 15, 1966.

Taking part in the work of the congress were more than 1000 scientists from 33 nations. A 35-member delegation, led by Academician L. I. Sedov, attended on behalf of the Soviet Union.

As at the previous congress in Athens, the agenda was extremely broad and varied. The discussions dealt with problems of a technical character - the use of satellites, spacecraft command-and-control systems, re-entry, and others - as well as problems within the sphere of biology - the effect of the physical factors of flight on living organisms (bioastronautics). Questions of space law were also considered at several sessions.

During one of the days of the congress the Second Symposium of the International Lunar Laboratory, which dealt with some problems relating to the possible arrival of man on the Moon, was also held.

Turning to a more detailed survey of the work of the bioastronautics section, one cannot help but observe that the papers presented were still limited to a study of the reactions of organic systems to specific spaceflight factors. A more profound analysis of organic response and a methodology based on research at the cellular level will be the task of the next few years.

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The section on bioastronautics considered:

1. Problems of general biology and the results of in-flight experiments;
2. Problems dealing with extra-vehicular activity and life-support systems;
3. Problems of a more general nature.

The delegates listened with great interest to a report by the director of the United States space medicine program, C. Berry. In general terms, the speaker described studies of almost all the organ systems of the body carried out during flights, of the Gemini 3, 8, 10, and 11 spacecraft. Evaluating the reaction of the vestibular apparatus, he noted that no significant deviations from the norm were observed. He regarded the "upside-down" feeling as a result of the redistribution of the blood and its flow toward the head. Berry went on to observe that no changes in visual perception had been recorded, and to call attention to quickening of the pulse rates up to 160-165 per minute during emergence from the capsule and, particularly, when re-entering the craft. The work involved in closing the hatch required great effort and produced considerable stress.

The experiments reported on by this speaker also dealt with calcium and phosphorus metabolism; chlorine, sodium, and potassium excretion; the nitrogen potassium, and fluorine level in the blood plasma; peripheral blood composition respiration; digestion; weight changes, etc.

The Spanish scientist, M. Nieto, discussed certain problems of pathophysiology under conditions of zero-gravity on the basis of comparative data obtained in the US and USSR. He assessed the results achieved by Soviet and American astronauts from the point of view of their emotional perception of discomfort associated with the lack of gravity and with the performance of physiological functions under these conditions.

The basic finding of this investigation was the need to create an artificial gravity on board the spacecraft for the purpose of approximating the astronaut's living conditions to those prevailing on the Earth. The Coriolis acceleration affecting human space pilots will be more easily endured by physiological systems than the state of weightlessness.

Special attention was paid to the problem of recording physiological tests during space flight, particularly biotelemetry on a protracted mission (reports by V. V. Parin, B. V. Yegorov, R. M. Bayevskiy, I. T. Akulinichev).

In the paper by Parin and his associates, the fundamental principles underlying the design of systems for the recording of physiological functions were reviewed. Of particular interest in this report were the results of experiments on the "Kosmos-110" satellite, during which tests with animals were conducted for the first time for the purpose of studying their physiological reactions to various previously programmed stimuli under space-flight conditions - mechanical and pharmacological effects on the carotid sinus, constriction of the carotid arteries, etc.

I. T. Akulinichev's paper was devoted to an analysis of specific circuit diagrams for miniaturized instruments for use in recording and transmitting physiological data to Earth.

A number of papers took up the problem of man outside the spacecraft. Questions dealing with locomotion and extra-vehicular activity were discussed (A. A. Gyurdzhian, USSR; R. Johnston, US). A. M. Genin (USSR) spoke of extended-time autonomous spacesuit activities. This author demonstrated the possibility, in principle, of ensuring the life and ability to work of a space-suited astronaut for a seven-day period in the event of an emergency pressure loss in the spacecraft capsule. The report of L. M. Seal (US) dealt with extra-vehicular working equipment and associated operations.

A number of speakers discussed the problem of changes in ocular functions during space flight.

C. Berry and D. H. Taylor (US) pointed out that the ocular function of the astronauts of the "Gemini" series underwent no changes; the sharpening of visual acuity, which had been expected, was not observed. Together with this, it was emphasized that the problem of visual perception on the Moon is of definite interest because of the absence of air. Available data support the belief that many of the customary visual sensations will either be altogether lacking or greatly modified. Sharp contrasts of light will evidently result in distorted judgments with respect to the size of objects, adversely affecting human vision. It is recommended, for this reason, that special sealed helmets and protective visors, capable of reducing optical and luminous distortions to a minimum, be designed ahead of time. Several methods were presented for the recruitment and preparation of personnel for manned Moon missions on the basis of individual vision peculiarities and specialized training.

The section also heard reports of a methodological character, including, in particular, a paper by L. D. Proctor (US) on the interpretation of electroencephalograms taken from humans and monkeys during flight simulation experiments.

The problem of the effect of G-forces in space flight was the subject of serious attention at the congress. In her report, A. R. Kotovskaya (USSR) considered several effects of cumulation and adaptation under repeated rotation. The author concluded that repeated exposure to accelerational forces may result /90
in various reactions in the animal organism which, on the one hand, are adaptive in character and, on the other, are, when cumulatively considered, of a markedly detrimental nature. Stress was laid on the importance and complexity of this problem. A. S. Barer (USSR) reported on the oxygen balance of the organism under the protracted influence of acceleration. Thorough analysis of the processes taking place in the organism under the influence of long-term acceleration provides a basis for the belief that resultant disturbances and malfunctions in the activity of the physiological systems of the body are due primarily to an oxygen insufficiency which is circulatory in nature.

Soviet researchers (V. Ye. Belay, P. V. Vasil'yev, and others) have demonstrated that the reaction of the organism to the introduction of various pharmacological substances is distorted under the influence of G-forces. This change in reaction depends on a host of factors, among them the properties of the pharmacological agent, the severity of the disturbances which occur during the acceleration period, the elapsed time following G-force exposure, etc. As a function of these causes, and their various combinations, the sensitivity of the organism may increase or decrease, along with the possibility that distorted reactions may take place.

These data provide a basis for the view that we are witnessing the emergence of a new branch of science - space pharmacology. Similarly, the research carried out by V. V. Parin et al. points to the development of space cardiology as a new area of medical application.

Problems relating to the selection of the atmosphere for the spacecraft cabin were discussed in a paper by B. Y. Welch (US), who considered several alternatives: pure oxygen; oxygen + nitrogen; oxygen + helium. Summing up the results of experiments performed on human beings, the author reached two basic conclusions:

1. The cabin atmosphere should show no deviations from normal atmospheric conditions on Earth;
2. The design features of cabin atmosphere-control systems should ensure maximum reliability in the adjustment of the gas mixture and minimum complexity in technical execution.

R. P. Mader and Y. Mills (US), in their report, analyzed the character and composition of harmful impurities arising in the spacecraft cabin during a flight, and described these impurities from the point of view of toxicology.

Questions having to do with radiation hazards during space flight and techniques for the measurement of the radiation level within and outside of the ship were discussed in a paper by D. Iving (US). The author pointed out that one of the most serious difficulties encountered by medical specialists engaged in space-flight support is the broad range of differences in the reactions of biological systems under the influence of cosmic radiation. Iving considers that

certain doses of radiation are partially accumulated, and that this calls for careful measurement. Referring to available data, the speaker proposed several methods of dosimetry during space flight. He observed that dosimetric monitoring systems are a part of the medical data base which, when tied in with other biological information, will enable the astronaut objectively to assess the situation on board and to make adequate decisions on a timely basis or to receive the proper commands from the control center on the Earth.

On the Moon, a particular peril will be presented by heavy ions, which may give rise to slow but profound changes in the organism (H. Shafer, US). For this reason, the problem of protection against these particles must be regarded as one of the most important in lunar mission planning.

A paper by A. R. Slonim (US) was devoted to dietary problems. This author studied the water metabolism in the body when dehydrated items were consumed as food. The use by astronauts of three dietary regimes was considered: fresh food, semiliquid food in tubes, and dried products with water. Experimental research was conducted in a special chamber at a temperature of 32°C. These experiments were continued for 4 to 6 weeks. It was established that if the fat content in the food is high, a tendency to bleeding and diarrhea is observed. The most favorable results were achieved through the use of a diet containing predominantly protein.

In addition to the problems mentioned above, the International Lunar Laboratory Symposium included a discussion of the problem of psychological compatibility in isolated groups like those to be formed by spacecraft crews (R. Angibout, France). An analysis was made of the behavior of isolated groups on submarines, which served as an analogy to living conditions on the Moon by virtue of the fact that the conditions prevailing outside the walls of the proposed lunar laboratories will be hostile to human existence. The preservation of a spirit of consensus within such groups, in the author's opinion, requires the following conditions: optimal conditions in the physical environment; an ensured sense of safety; strict scheduling of work, relaxation, and sleep; and, finally, a properly selected psychological group structure. The author places particularly great stress on the organization of leisure and ascribes a major role to television, which he regards as the sole meaningful mode of communication with life on Earth.

W. Kuchneger (US) read a study dealing with an analysis of the physical capabilities of man on the Moon. The investigations were conducted on a stand which simulated "lunar attraction" (the research subject was suspended on the stand at an angle of 9°36' to the horizontal); under these conditions, calculations were made of the consumption of electricity for walking, running, and jumping without a spacesuit or with a spacesuit under pressure. /91

A highly detailed mathematical analysis of all forms of locomotion on the Moon was presented by R. Margaria (Italy), with the author concluding that the optimum mode will be the jump, to enable maximum utilization of muscular energy. Margaria's data were based on a calculation of the speed of movement on the Moon, with proper consideration of the change in the force of pressure, the step frequency, and various factors of foot-to-surface friction when running and

jumping. The author concluded that the reduction in gravity to one sixth of that on Earth will impede, rather than facilitate, man's movement on the lunar surface.

Problems connected with emergence from the spacecraft onto the lunar surface, human life under conditions of reduced gravity, and possible complications after return to Earth were analyzed in a report by H. A. Bjurstedt (Sweden) and H. Strughold (US).

R. Armstrong (US) considered the question of life support on the Moon from the standpoint of the utilization of locally available resources. It is this author's belief that the major criterion to be used by the engineers who will ultimately design a system for this purpose must necessarily be the duration of the expedition. From this point of departure, Armstrong considers a number of systems:

1. For a short mission - product supplies;
2. For an expedition of average duration - semi-closed regenerative systems;
3. For extended expeditions - systems with a complete regeneration cycle.

The report contained diagrams and numerical calculations, and was accompanied by slides showing working installations, equipment, and stand cameras. The system recommended by the author provides for a complete cycle of oxygen and water, but is "open for food."

The paper by N. V. Peary (Great Britain) dealt with a closed ecological system. The author feels that algae offers no advantages over higher forms of plant life in terms of oxygen regeneration, and proposes the use in the system of higher plants, from the leaves of which it is possible to derive sufficient amino acids to satisfy the vital requirements of man.

Summarizing the work of the bioastronautics section, it is noteworthy that a rich body of material has been gathered during the past year on the study of the physiological functions of the organism under spaceflight conditions or in environments closely resembling them. Efforts have been made to discover the mechanisms governing organic physiological reactions under these conditions. Broad-based theoretical groundwork is now under way in preparation for manned lunar missions, a fact which was amply attested to by the variety of papers heard at the International Lunar Laboratory Symposium.

Plans call for the convening of the next, XVIII, congress of the International Astronautics Federation in Belgrade in the fall of 1967.

CONCISE DICTIONARY-HANDBOOD ON SPACE BIOLOGY AND MEDICINE

"Meditsina" Publishing House is releasing a "Concise Dictionary-Handbook on Space Biology and Medicine" ("Kratkiy slovar'-spravochnik po kosmicheskoy biologii i meditsine") under the editorial supervision of A. I. Burnazyan, Yu. G. Nefedov, V. V. Parin, V. N. Pravetskiy, and I. M. Khazen. The book contains 35 printer's sheets (about 560 pages).

The book has been compiled by the outstanding specialists in the area of space biology and medicine. It represents the first attempt to enunciate the doctrine of this scientific discipline. In addition to articles having a direct bearing on space biology and medicine, the handbook also lists numerous terms from allied branches of knowledge (technical sciences, physics, chemistry, mathematics, medical cybernetics, electronics, and other disciplines) which will permit the reader, when using the dictionary, to familiarize himself sufficiently with the material presented in it with no need for frequent reference to other sources.

The book was written not only for biologists, physicians, and designers, but also for other specialists engaged in the area of astronautics. This dictionary-handbook may also, to some degree, prove useful to aspirants and students in related institutions of higher learning.

PUBLICATION OF THE JOURNAL "ASTRONAUTICA ACTA" /92

(Brief article on the publication of a new journal - Translation omitted)

INTERNATIONAL PRIZE AWARD

(Brief article from *Press Release*, No. 29, 1966 - Translation omitted)

NASA HOUSTON CENTER FORMS NEW DIVISION

(Article from *Aviation Week and Space Technology*, Vol. 84, No. 21, p. 93, 1966 - Translation omitted)

38th ANNUAL CONFERENCE OF THE SPACE MEDICINE ASSOCIATION (USA)

(Article from *Aerospace Medicine*, Vol. 37, No. 8, 1966, p. 886 - Translation omitted)

IN MEMORY OF THE RECENTLY KILLED AMERICAN ASTRONAUTS

The editorial board of the journal "Kosmicheskaya biologiya i meditsina" ("Space Biology and Medicine") wishes to express its sincere condolences to their American colleagues and their deep sympathy to the families of the crew members of the "Apollo I" spacecraft, astronauts Virgil Grissom, Edward White, and Roger Chaffee, who perished on January 27, 1967 at the Cape Kennedy Eastern Test Range. /93

The death of these courageous space pioneers has profoundly moved not only the people of the United States, but has touched a deep chord of pain in our hearts as well. Virgil Grissom, Edward White, and Roger Chaffee were men of a new profession which, regardless of state or national affiliation, made them

representatives of the entire world. Together with Soviet astronauts, they were trail-blazers to a better understanding of the universe which surrounds us and to the conquest of outer space.

We, whose task it is to stand guard over the health and life of astronaut personnel, feel with particular pain this great tragedy and call upon our American research colleagues to do everything necessary to safeguard the life and limb of their astronauts, by ensuring maximum safety in space-related experiments.

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